JACQUES, WHITFORD AND ASSOCIATES LIMITED
Consulting Engineers

Open File Report 86-6

A STUDY OF INDUSTRIAL MINERALS
USED IN
OIL AND GAS EXPLORATION
ON THE EASTERN CANADIAN OFFSHORE

by

JACQUES, WHITFORD AND ASSOCIATES LIMITED
with
CLELAND, DUNSMUIR CONSULTING LIMITED

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BY

JACQUES, WHITFORD AND ASSOCIATES LIMITED
WITH
CLELAND, DUNSMUIR CONSULTING LIMITED

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Halifax, Nova Scotia

February, 1986

EXECUTIVE SUMMARY

This report has been prepared by Jacques, Whitford and Associates and Cleland, Dunsmuir Consulting Limited, under the auspices of the Mineral Development Agreements (MDA) to examine the use of industrial minerals within the Oil and Gas Exploration Industry on Canada's East Coast.

Since 1960, petroleum companies have drilled 234 deep wells, some in excess of 5000 meters. At such depths geostatic pressures and other geologic conditions must be controlled by the drilling fluid without impeding the penetration rate of the drilling operation. The drilling fluid must control well conditions through its chemical, mechanical and physical properties, many of which are governed by industrial minerals or additives derived from industrial minerals. Drill mud service companies prepare the drilling fluid and thus control the consumption of industrial mineral in oil well drilling.

All drilling fluids consist of three components: liquid phase, colloidal, and inert fractions. They are classified on the basis of the continuous component of the fluid, i.e., water base, oil base or pneumatic. The type of drilling fluid selected for a well will depend upon the expected formation conditions, fluid availability, and cost. The water base drilling fluids are the most commonly used type throughout the world. The oil base drilling fluids, which began as specialty fluids, are gaining greater use because of improved drilling results.

The drilling fluids are used to control the conditions encountered down the well bore, such as sloughing shales, lost circulation zones, subsurface pressures, as well as cooling and lubricating the bit and carrying the cuttings to the surface without damaging producing formations. The industrial minerals play key roles in drilling fluids, such as weighting agents (barite, hematite); viscosifiers (bentonite, attapulgite); shale controllers (sylvite, halite); dispersants and thinners (lignite); alkalinity and pH controllers (calcite, sodium carbonate); lost circulation materials (mica, salt, calcite); and others.

The mineral barite is the most widely used mineral as a weighting agent. Commercial deposits of barite exist in Atlantic Canada and have supplied some of the requirement.

Oil and gas wells require cemented casings to protect wells and to control formation conditions. Cement is second only to barite in terms of value used in the offshore drilling operations.

Drilling mud and cement comprise around 1.7 and 0.7 percent, respectively, of total drilling costs, a substantial reduction from the early 1980's. The industrial minerals component of mud and cement seems to comprise around 2 percent of total drilling costs.

A review of North Sea, U.S. and Canadian experience shows that, except for barite use, which is fairly consistent, the use of different mineral products in muds is highly variable over time and from place to place. To identify minerals specifically used in the East Coast offshore, a sample of 29 wells for mud and 28 wells for cement was selected. The sample, which represents a third of total drilling since 1980, showed 21 minerals in use in mud and cement. Barite accounted for over 70 percent of the weight of minerals in mud and American Petroleum Institute (API) Class G cement for over 99 percent of materials in cement. Only bentonite, potash, lignite, salt, and hematite were found in total quantities of 500 tonnes or more.

The main factors determining the type of material used are current industry practice, hole conditions, and price. These factors seem to have produced a general decline in the East Coast offshore in the use of barite and, even more so, bentonite, lignite, and salt. Potash has shown some increase. The possibility of increased use of oil base muds would tend to further depress the use of most mineral products. Hematite could possibly begin to displace barite as a weighting agent, but abrasiveness , handling and price concerns may limit this possibility.

For a given material, price is the main criterion determining source. Quality must be within the range of API specifications but is otherwise a minor consideration. Availability is usually not an issue. Corporate ownership patterns produce a variety of conflicting effects but their total influence is minor, relative to price.

Market prospects for industrial minerals in the East Coast offshore are limited due to a number of factors. Overall activity is depressed and likely to remain that way for a few years. Most commodities are in declining use and prices, especially of barite, are depressed. Atlantic Canadian mineral producers already seem to be capturing available markets.

SOMMAIRE EXECUTIF

L'entreprise Jacques, Whitford and Associates, sous les auspices de Mineral Development Agreements («MDA»), a étudié les minéraux utilisés dans l'industrie de l'exploration côtière du gaz et du pétrole à l'est du Canada.

Depuis l'an 1960, les compagnies de pétrole ont creusé 234 puits profonds dont quelques puits approchent plus de 5000 mètres de profondeur. On doit contrôler les pressions géostatiques et les autres conditions géologiques à ces profondeurs et ce contrôle est accompli avec l'aide de la boue de forage sans affecter la vitesse de pénétration du forage. Les boues de forage contrôlent les conditions du puit en contrôlant ses propriétés chimiques, physiques et mécaniques. Ces mêmes propriétés sont sous l'influence des minéraux ou de leurs additifs. L'industrie du forage est desservie par des compagnies qui produisent les boues de forage qui par la suite règlent la consommation des minéraux employés dans l'industrie de forage des puits de pétrole.

Les boues de forage comprennent trois parties constituantes: les fractions liquides, colloïdales et inertes. N'importe quelle boue de forage est classée d'après sa permanence à base d'eau, d'huile ou d'air. On sélectionne la boue de forage d'après ses conditions de formation, sa disponibilité et son coût. La boue de forage à base d'eau est celle la plus employée au monde. Par contre, la boue de forage à base d'huile, utilisée auparavant dans des conditions spéciales, prend de l'avance grâce à des meilleurs résultats durant le forage.

Les boues de forage servent à contrôler les conditions du puit telles que les éboulements de formations, les zones sans circulation des boues de forage et les pressions géostatiques. De même, elles refroidissent et lubrifient le trépan et transportent les débris de forage à la surface sans endommager les roches réservoir. On produit les boues de forage à l'aide de différents minéraux: les agents de pesage (le barytine et l'hematite), les agents de viscosité (le bentonite et l'attapulgite), les agents d'éboulement de formation (le sylvite et l'halite), les agents de dispersement et de dilution (le lignite), les agents pour l'alcalinité et le pH (le calcite et le carbonate de soude), les minéraux servant à contrôler la perte de circulation (le mica, l'halite, le calcite), et ainsi de suite.

Le barytine comme agent de pesage est beaucoup utilisé. Les gisements commerciaux de barytine sont situés aux provinces atlantiques du Canada et sont utilisés à cet égard.

Les puits de gaz et de pétrole exigent des tubages en ciment afin de les protéger et de contrôler les conditions de formation. Le ciment est presqu'aussi important que le barytine dans les opérations côtières de forage.

Les boues de forage et le ciment comptent environ 1.7 et 0.7 pourcent (respectivement) du coût total de forage. Les parties constituantes des minéraux de l'industrie semblent comprendre approximativement 2 pourcent du coût total de forage.

D'après les expériences des Anglais, des Norvégiens, des Américains et des Canadiens, l'usage de différents minéraux dans les boues de forage est grandement varié, sauf l'usage du barytine dont tous ces pays utilisent en commun. On a évalué les données de boues de forage obtenues de 29 puits et celles du ciment employé dans 28 puits foragés à l'est côtière afin d'identifier la présence des différents minéraux. Ces données, représentants celles obtenues d'un tiers de tous les puits foragés depuis 1980, ont indiqué la présence de 21 minéraux dans les boues de forage et le ciment.

Le barytine comprenait 70 pourcent de tous les minéraux employés dans les boues de forage et 99 pourcent dans le ciment. Seulement le bentonite, le potasse, le lignite, l'halite et l'hematite formaient une quantité de 500 tonnes ou plus.

En général, le genre de minéral utilisé dans les boues de forage est choisi d'après les habitudes courantes de l'industrie, les conditions de forage de puit et le coût. Ces facteurs semblent avoir influencé d'une façon générale une diminution de l'usage du barytine, et d'une autre façon, l'usage diminué du bentonite, du lignite, du halite dans le forage de puit à l'exploration côtière de l'est. Le potasse, cependant, démontra un plus grand usage.

Avec l'avènement de l'emploi de boues de forage à base d'huile, il y a une bonne possibilité que l'emploi des minéraux soit diminué plus encore. L'hematite pourrait remplacer le barytine comme agent de pesage dans cet instance, par contre, l'abrasif, le maniement et le coût limiteraient son usage.

Le prix est le facteur principal dans l'emploi de n'importe quel minéral dans cette industrie. La qualité doit être maintenue selon les spécifications de l'API, mais autrement ce facteur n'occupe pas une grande importance. De même, la disponibilité du minéral ne constitue pas un facteur important. Seules les practiques des compagnies exercées dans cette industrie peuvent parfois exprimer un effet sur le coût des minéraux, mais cet effet est relativement mineur.

Le marché des minéraux employés dans l'industrie côtière de forage à l'est est affecté par certains facteurs. Les exercises de forage et de construction sont présentement ralentis et il semble que cette situation va se faire ressentir pour plusieurs années. L'usage de la plupart des produits est également réduit, de même que leurs prix et, en particulier, celui du barytine.

Les producteurs de minéral dans la région atlantique du Canada semblent déjà prendre avantage de ce marché.

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1.0 INTRODUCTION

1.1 Background and Project Rationale

This report has been prepared under the auspices of the new Mineral Development Agreements (MDA) for the purpose of examining the use of industrial minerals within the Oil and Gas Exploration Industry on Canada's East Coast.

Exploration drilling for oil and gas off the Canadian East Coast since 1960 has incorporated many deep wells, some in excess of 5000 m. At such depths, subsurface rock pressures and the competence of wall rocks in the borehole require the use of specialized drilling fluids. The drilling fluids contain additives to moderate the performance, many of which are derived from industrial minerals. Recent publications state categorically that the Oil and Gas Drilling Industry remains the largest consumer of functional industry minerals within the U.S. The object of this study, therefore, is to examine the use of industrial minerals in Canada's offshore programs, and to determine what areas, if any, may be productive for the local industrial mineral interests to pursue.

The contract to examine the use of industrial minerals was awarded in July, 1985 to Jacques, Whitford & Associates Limited, in association with Cleland, Dunsmuir Consulting Limited. The technical concerns to be addressed were outlined by the Statement of Work, which is attached as Appendix 1. The contract required work in 3 phases:

- information on the producers and consumers of industrial minerals;
- the application of industrial minerals in drilling muds;
- commercial and marketing aspects of industrial minerals used in the exploration programs.

1.2 Study Participants

The contract was awarded in July, 1985, under the direction of Mr. D. Stonehouse, Scientific Authority. The prime consultant on the project, Jacques, Whitford and Associates Limited (JWA), assigned Mr. J.A. Amirault, P.Eng. as project manager and principal investigator. Other personnel assigned were as follows:

- Mr. B. Wile, Mining Engineer
- Mr. G. Sheppard, Mining Engineer

Economic issues were addressed by Cleland, Dunsmuir Consulting Limited:

- Mr. M. Cleland, Senior Business Consultant
- Ms. M. Dunsmuir, Senior Business Consultant

1.3 Organization of the Report

The Statement of Work clearly requests that the report address the use of industrial minerals for offshore applications only, as well as issues concerned with the corporate linkages involved between the mine and final use of the mineral. To add perspective, however, a brief overview of the historical development of the East Coast offshore drilling activity and some of the technicalities of drilling operations are also presented.

The report is presented in 9 Sections. Following this introductory section on project rationale and report organization, Sections 2 to 5 discuss the technical aspects of industrial mineral usage on the Eastern Canadian offshore exploration including oil and gas exploration industry development and recent highlights, the functions of drilling fluids, the roles of industrial minerals, the major aspects of well operations, and mud circulation system.

The more commonly used industrial minerals are discussed in Section 5 in which geological, mining, beneficiation and marketing information is presented.

Sections 6 to 9 present the economic considerations of industrial mineral usage in the Eastern Canadian oil and gas exploration scene. The industrial minerals market is placed into perspective with regard to marine oil and gas exploration; the data base of exploration wells surveyed for the project is established and the quantities of minerals used regionally is introduced. The current market conditions are developed in Section 8, while the major factors affecting industrial mineral usage are discussed in Section 9.

1.4 Acknowledgements

The authors gratefully acknowledge the willing participation of all those assisting in the assembly of data and the preparation of this report. We particulary wish to thank Mr. D. Stonehouse, Scientific Authority, for his direction and guidance during the planning and conduct of this study. Other federal and provincial agencies such as the Department of Mines and Energy, Canada Oil and Gas Lands Administration, and the Newfoundland Petroleum Directorate were also helpful in the assembly and analysis of the data. Finally, the economic considerations work would not have been done without the willing assistance of representatives of the mud and well service companies, operating in Eastern Canada.

2.0 OFFSHORE OIL AND GAS EXPLORATION IN EASTERN CANADA

2.1 Historical Milestones

The first oil and gas exploration offshore in eastern Canada occured in 1959 when Mobil Oil Canada Ltd. (Mobil) conducted an aerial magnetic survey in the vicinity of Sable Island. The following year Mobil used seismic exploration to explore a 1.1 million acre area under a provincial license. In 1963 Shell Canada Resources Limited (Shell) obtained a provincial license for 20 million acres of the Scotian Shelf. By 1965 most of the Canadian Shelf was under license to various international petroleum companies.

Exploration drilling off East Coast Canada began in 1960 when two wells were drilled by AMOCO Canada Petroleum Company Limited (AMOCO) on the Grand Banks of Newfoundland. The first well off Nova Scotia drilled by Mobil in 1967 near Sable Island, encountered an overpressured zone, considered as favourable areas for oil and gas accumulation.

Results of exploration drilling on the East Coast prior to 1979 were only marginally encouraging. In that year two significant discoveries renewed interest in the East Coast. The first was a significant gas show drilled by Petro Canada Incorporated (Petro-Canada) for Mobil in the Venture D-23 well located east of Sable Island. The second was a significant oil discovery made at the Hibernia P-15 well by Chevron Standard Limited (Chevron) on lands under permit to Mobil.

Figure 2.1 shows the areas of interest of oil and gas exploration on the East Coast (after Oilweek 1982). For the purposes of this report, Offshore East Coast Canada is considered to be the areas shown and generally known as the Scotian Shelf, Grand Banks and Labrador Shelf. Within these areas to 1985 a total of 114 wells have been drilled on the Scotian Shelf, 89 on the Grand Banks;

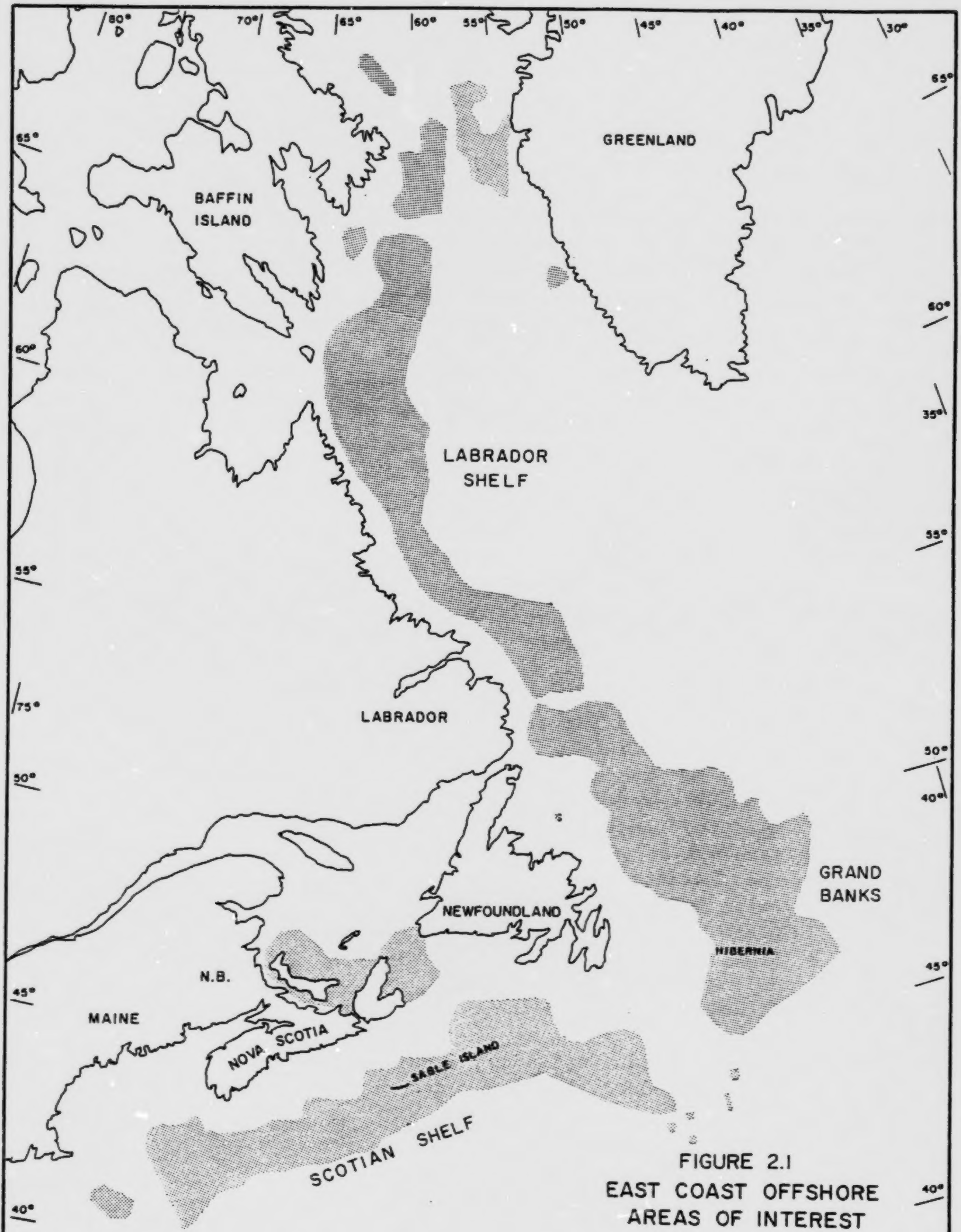

GREENLAND
BAFFIN ISLAND
LABRADOR SHELF
LABRADOR
GRAND BANKS
HIBERNIA
NEWFOUNDLAND
N.B.
MAINE
NOVA SCOTIA
SABLE ISLAND
SCOTIAN SHELF
80°
70°
65°
60°
55°
50°
45°
40°
35°
30°
75°

FIGURE 2.1
EAST COAST OFFSHORE
AREAS OF INTEREST

and 31 on the Labrador Shelf. Principal operators, wells drilled and significant discoveries are shown on Table 2.1.

2.2 Geological Setting

Scotian Shelf

The Scotian Shelf is one of Canada's largest sedimentary basins; having an area in the order of 16 million hectares, extending 700 kilometers from Georges Bank in the west to the Laurentian Channel in the east. The width varies from 120 to 130 kilometers.

Sediments of the Scotian Shelf are of greatest thickness in the Sable Island Sub-basin where most major oil and gas discoveries of the Scotian Shelf have been made.

The thick layers of sediments in the Sable Island Sub-basin were formed during several geologic periods, beginning in the Jurassic period when thick layers of salt were deposited in a rift basin as the North American and the North African Continents separated. Later in the Jurassic, thick belts of limestone, including the Baccaro carbonate front, were deposited. During the Cretaceous period, coarse clastic sandstones known as the Missisauga Formation were deposited over the shelf margin and the Baccaro carbonate front. The clastics deposited on the shelf graded from coarse to fine grained, and formed sandstones to shales. Later in the Cretaceous, thick subsea deltas consisting of sand were created, extending across the Scotian Shelf completely burying the carbonate mass. In late Cretaceous time, layers of shale were deposited over these subsea deltas. Figure 2.2 shows the stratigraphy of the lithologic units of the Scotian Shelf.

The gas producing zones of the Venture field are found in interbedded sandstones and shales of the Missisauga Formation.

TABLE 2.1: Significant Discoveries on the East Coast of Canada

LOCATION	OPERATOR	WELLS	DISCOVERY
Scotian Shelf	Shell-Petro-Can	Uniacke	Gas/Condensate
	Mobil	Citnalta	"
	Petro-Can	Banquereau	"
	Mobil	Arcadia	"
	Mobil	Olympia	"
	Mobil	Venture	"
	Mobil-Tetco	Sable Island	Oil and Gas
	Shell	Primrose	"
	Mobil	S. Venture	Gas/Condensate
	Mobil-Tetco	Thebaud	"
	Mobil-Tetco	Cohasset	Oil
	Shell	Onondaga	Gas/Condensate
	Shell-Petro-Can	Glenelg	"
	Texaco-Shell	Intrepid	"
	Shell-Petro-Can	Alma	"
	Mobil	West Venture C-62	"
	Mobil	West Venture N-91	"
	Husky/Bow Valley	Chebucto	"
Grand Banks	Mobil	North Dana	Gas/Condensate
	Mobil	South Tempest	Oil
	Husky/Bow Balley	Trave	Gas/Condensate
	Mobil	Nautilus	Oil
	Mobil	South Mara	Oil and Gas
	Mobil	Ben Nevis	"
	Mobil	Hebron	Oil
	Petro-Can	Terra Nova	Oil
	Mobil	Hibernia K-18	Oil
		B-08	Gas and Oil
		B-27	Oil
		C-96	Oil
		P-15	Gas and Oil
		K-14	Oil and Water
Labrador Shelf	N/A	Hekja	Gas/Condensate
	Eastcan	Snorri	"
	Eastcan	N. Bjarni	"
	Eastcan	Bjarni H-81	"
	Eastcan	Gudrid	"

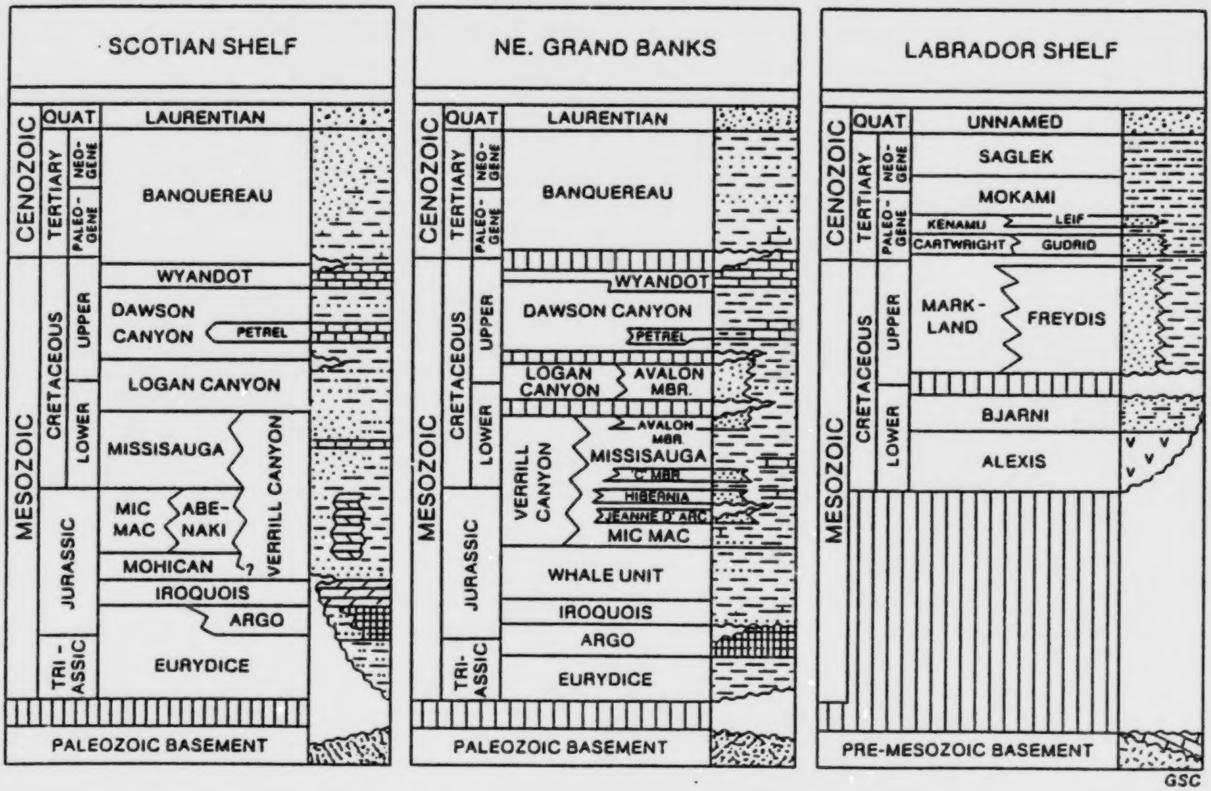

SCOTIAN SHELF
NE. GRAND BANKS
LABRADOR SHELF
CENOZOIC
MESOZOIC
QUAT
TERTIARY
NEO-GENE
PALEO-GENE
CRETACEOUS
UPPER
LOWER
JURASSIC
TRI-ASSIC
LAURENTIAN
BANQUEREAU
WYANDOT
DAWSON CANYON
PETREL
LOGAN CANYON
MISSISAUGA
VERRILL CANYON
MIC MAC
ABE-NAKI
MOHICAN
IROQUOIS
ARGO
EURYDICE
PALEOZOIC BASEMENT
AVALON MBR.
'C' MBR
HIBERNIA
JEANNE D' ARC
WHALE UNIT
UNNAMED
SAGLEK
MOKAMI
KENAMU
LEIF
CARTWRIGHT
GUDRID
MARK-LAND
FREYDIS
BJARNI
ALEXIS
PRE-MESOZOIC BASEMENT
GSC

FIGURE 2.2: Generalized Stratigraphic Columns of the Scotian Shelf, Northeast Grand Banks and Labrador Shelf
(Grant et al, 1986)

Hibernia

The Grand Banks of Canada's Continental Shelf extend more than 400 kilometers eastward from Newfoundland and approximately 500 kilometers south to north (Figure 2.1).

The Hibernia field is located on the Grand Banks, approximately 320 kilometers southeast of St. John's in water depths ranging from 76 to 86 meters. The Hibernia field is located on the western periphery of the Avalon Basin. The total thickness of the sediments along the axis of the Avalon Basin is believed to exceed 15,000 meters. The Hibernia structure is a large roll-over anticline which is bounded by normal faults, striking northwest. The basement rocks of the Hibernia field consist of Paleozoic and Precambrian rocks which are overlain by Tertiary and Upper to Lower Cretaceous sediments. Figure 2.2 shows the stratigraphy of the lithologic units of the Northeast Grand Banks.

Three major unconformities divide the stratigraphic column into four distinct zones. Four sandstone reservoirs have been recognized in the Hibernia field: the Avalon Zone; the "B" Seismic Marker Zone; the Hibernia Zone; and the Jeanne d'Arc Zone. All of these reservoirs are situated within the Lower Cretaceous except for the Jeanne d'Arc sands which fall into the Lower Cretaceous/Upper Jurassic transition zone.

Labrador Shelf

The Labrador Shelf contains two basins; the Saglek Basin and the Hopedale Basin which are separated by the Okak Arch.

The rocks on the Labrador Shelf are Mesozoic to Cenozoic deposits, overlying Paleozoic basement rocks in the south and Precambrian basement rocks to the north. Paleozoic sequences contains potentially important reservoir horizons, but the hydrocarbons encountered to date off Labrador may have had their source in adjacent Cretaceous or Tertiary strata. Figure 2.2 shows the stratigraphy of the lithologic units of the Labrador Shelf.

The structural style of the Labrador margin differs considerably from that of the two previously discussed areas where salt deformation plays a key role. Basement block faulting and the associated drape of overlying reservoir beds constitute the main hydrocarbon plays on the Labrador Shelf. Other plays include reservoirs in porous Paleozoic facies associated with basement highs, stratigraphic closures at the depositional edges of the Bjarni and Gudrid Formations and faulting in a thick unstable (possibly due to overpressure) sediment pile in the vicinity of the Corte Real Well. The lack of reservoir beds is a problem in the Labrador Shelf. The Bjarni Formation is a thick, arkosic, continental sand and has an average porosity of about 12%. The Gudrid Formation has porosities up to 25%, but is relatively thin and of limited extent.

2.3 Major Offshore Features

The inherent characteristics of the 3 frontier areas (Scotian Shelf, Grand Banks, Labrador Shelf) are being continually defined as experience on the offshore broadens. These major features, briefly discussed following, dramatically affect the requirements of the drilling system and specifically the muds and cements used down the well bore. The operators are having greater success at predicting the conditions which will be encountered in the well and are better informed as to which admixtures are most successful.

Depth

The depth of an exploration well will determine the lithostatic pressures which must be balanced by the drilling fluid. The deeper the well, the higher the lithostatic pressure, therefore requiring greater amounts of weighting material. Wells drilled off the

East Coast of Canada are being drilled to depths of over 5000 meters and, therefore, require large quantities of weighting materials, such as barite.

Overpressured Zones

Overpressured zones require heavier than normal mud weights to balance the "bottom hole" pressures. Barite (SG 4.5) and other high density weighting agents, such as hematite (SG 5.1) or galena (SG 7.4), are added to the mud. The over-pressured zones of the Scotian Shelf have been found to contain abundant reservoir rocks and, therefore, will be explored further.

Temperature

Exploration wells being drilled offshore in Eastern Canada experience what is known as the geothermal gradient; elevated temperatures with increasing depths. The "normal" geothermal gradient is 1.8°C per 100 meters of depth, however, it may double in overpressure zones. The increase in temperatures causes an increase in viscosity so thermally stable agents, such as lignite, must be incorporated into the mud composition.

Shale Conditions

Layers of shales and clays are frequently encountered in the exploration wells drilled on the East Coast of Canada. Sloughing of shales and clays tends to occur when these layers are allowed to hydrate and swell. The prevention of sloughing shales and clays requires the addition of industrial minerals and other materials, such as potash, calcium chloride and salt.

Anhydrite Zones

Anhydrite zones are commonly encountered in East Coast Canada exploration wells. To successfully drill through these zones, the anhydrite must be treated with soda ash and/or barium carbonate. Alternatively, a calcium-water base mud system may be used.

Salt Zones

The penetration of salt zones is achieved usually with a gypsum-starch mud as normal muds would cause the salt formation to deteriorate. In drilling massive salt zones, the mud is often saturated with salt to prevent the salt formation from dissolving, resulting in deterioration of the drill hole.

Lost Circulation Zones

Lost circulation zones are problematic in that valuable materials are lost and geostatic pressures are not being controlled. Lost circulation zones are typically encountered in reefs and eroded limestone surfaces, faults and fissures and porous formations. Industrial minerals such as mica, lignite, clays, fibrous mineral wool, perlite and asbestos fibers are used to control lost circulation by bridging these openings. Many non-mineral products are used as well. In the East Coast offshore walnut shells are common.

2.4 Employment and Expenditures

Employment within the offshore exploration industry is directly proportional to the number of rigs operating. Total employment is in the order of 200 persons per operating rig. For example in 1984, a total of 2000 persons were employed operating and servicing 10 rigs offshore Nova Scotia. Clearly, offshore drilling operations have a major impact on employment in Atlantic Canada.

Exploration expenditures are also directly proportional to the level of activity. Within Nova Scotia alone, expenditures range from $257 million in 1982 to $618 million in 1984 (Canada - Nova Scotia Oil and Gas Board Annual Report, 1984).

3.0 WELL OPERATIONS

3.1 Participants

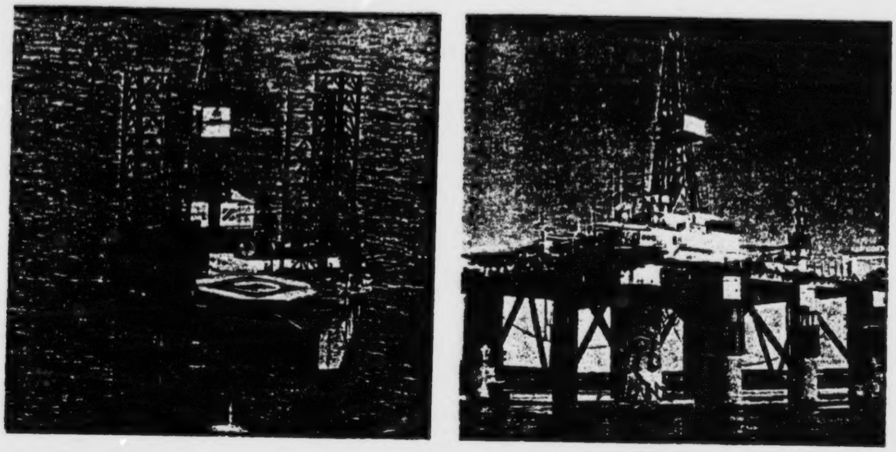
Offshore oil and gas exploration is a complex and expensive activity, which necessitates the co-operative involvement of several participating groups including: lease holders and operators, rig owners and operators, well service and speciality companies. Most are large, international companies, which follow the global petroleum frontier. There are four such groups present on the Eastern Canadian offshore; examples of which are provided below:

Lease holder/operator (generally major oil companies)	Mobil Shell Petro Canada
Rig Operators	Zapata Sedco Rowan
Service Companies	National Mud Dresser Magcobar NL Baroid Technifluids
Speciality Companies	Dowell-Schlumberger Sperry Halliburton Nowsco Well Service

It is the mud and well service companies which consume industrial minerals.

3.2 Drill Types

There are four types of mobile offshore drilling systems, submersible, jackup, ships or barges and semi-submersible. Of these, the major types used offshore in Eastern Canada are primarily the jackup and the semi-submersible as illustrated by Figure 3.1.



ZAPATA SCOTIAN *Jackup unit, three triangular legs, electro-mechanical jacking system*

COMPANY *Zapata Off-Shore Company*

WATER DEPTH *200 feet (61 m)*

RATED DRILLING DEPTH *25,000 feet (7 620 m)*

YEAR BUILT *1981*

SHIPYARD *Promet Limited, Singapore*

LENGTH *230 feet (70 m)*

WIDTH *212 feet (65 m)*

DERRICK HEIGHT *147 feet (45 m)*

KEEL TO MAIN DECK *26 feet (8m)*

LIVING QUARTERS CAPACITY *94*

SEDCO 709 *Dynamically positioned semi-submersible, twin-hulled, column stabilized*

COMPANY *Marime Drilling, S.A. (SEDCO)*

WATER DEPTH *6,000 feet (1 829 m)*

RATED DRILLING DEPTH *25,000 feet (7 620 m)*

YEAR BUILT *1977*

SHIPYARD *Hawker-Siddeley Canada Ltd., Halifax*

LENGTH *296 feet (90 m)*

WIDTH *218 feet (66 m)*

DERRICK HEIGHT *160 feet (49 m)*

KEEL TO MAIN DECK *113 feet (34 m)*

LIVING QUARTERS CAPACITY *97*

FIGURE 3.1: Typical Jackup and Semi-Submersible Drilling Units
Source: Nova Scotia Oil and Gas Report. 1984

The Jackup Rig

Jackup rigs are built to float, enabling them to be towed on site. Once positioned at a drill site, these rigs jack their legs down onto the ocean floor, and raise the hull of the structure out of the ocean to a sufficient height above wave action. These rigs are suitable for drilling in severe weather conditions and are able to drill in water depths of 15-140 meters.

Semi-Submersible Rigs

These rigs are designed with hulls upon which the drilling platform floats. Once the rig is towed into position, the hulls are partially flooded causing the hulls to submerge to a depth slightly below the water surface, thereby reducing the effects of surface wave action and making them stable. The drilling platform is above the zone of wave action. Semi-submersible rigs are often selected because of their excellent stability in rough, deep seas. Semi-submersibles may operate in water depths up to 360 meters when using anchors and chains to maintain the rig's position. Rigs using dynamic positioning can operate in water depths up to 2000 meters.

Rotary Drill System

Regardless of the type of systems used and separate from the marine issues relating to transportation and support of the rig, both types use a rotary drill system. A rotary drill system is composed of the following components: drill string and bits, supporting equipment (derrick) and hoisting gear (draw works), rotating system (rotary table) and drill fluid circulation system.

This report will focus on drilling fluids and cements; however, a few comments are required to enable a proper perspective of the drilling operations. Marine drilling operations require special modifications of drilling systems to explore for hydrocarbons. The most obvious difference is the drill platform itself, which may be floating or supported by legs, many meters above the ocean floor. In the case of jackup rigs a marine riser extends from the ocean floor to the Blow Out Preventer (BOP) in the lower decks of the rig. In the case of the semi-submersible rig, the BOP stack is located on the ocean floor and a marine riser extends to the floating drill platform.

3.3 Typical Drilling Operations

Once the area to be drilled has been spotted by survey buoys, the drill rig is moved into position and set up over the drillsite. Once the rig is secured into position, the well is spudded, drilled to a certain depth and a conductor set into position. In the case of jackup rigs the conductor runs to the bottom of the rig. Fixed to the top of the Conductor pipe is the Blow Out Preventor (BOP). In the case of semi-submersible rigs, the conductor pipe ends at the sea floor where the BOP is mounted on the well head and a marine riser extends from the top of the BOP to the bottom of the drill floor.

The well is drilled with a rotary tricone bit of smaller diameter than the conductor pipe. This bit is on the end of a drill string, consisting of collars and drill pipe. The drill string is lowered into the conductor hole. When the bit is on the bottom of the conductor pipe, a drilling fluid is pumped and circulation begins.

The revolving bit grinds and cuts through the formations as drilling fluid is pumped down the drill string, and returns to the surface through the annulus between the drill pipe and the casing.

The drilling operation proceeds on a 24 hour basis, stopping only to add additional drill pipes and to change the bit. At a predetermined depth below the water, or when problem formations are encountered, the drill string and bit is tripped out of the hole and the surface casing is run and cemented in place. The length of surface casing varies from location to location and is dependent upon soil and rock conditions near its surface. A bit of smaller diameter is then used to continue drilling below the surface casing.

Once the drilling has reached a predetermined depth, the intermediate casing string is run. The intermediate casing runs all the way from the surface down through the surface casing to the bottom of the intermediate hole. The intermediate casing serves to control formations which are sloughing under high pressure. These formations can be controlled while being drilled by suitable fluids, but before drilling to final depth they must be cased off or cemented.

The final part of the hole contains the target zones where the potential for hydrocarbons may exist. Drilling is conducted in the same manner as described. Great care is taken during drilling through the potential hydrocarbon bearing formation so as not to flow the formations unexpectedly. When the hole is at total depth, the formations are tested for potential hydrocarbons.

If testing is successful in identifying hydrocarbons, the well may be equipped for production which is beyond the scope of this study. If unsuccessful, the down hole equipment is removed, and the well cemented from bottom to top.

3.4 Drilling Fluids Circulation System

This section introduces the components of the fluid circulation system: the mud pump, drill string, annulus, shale shaker, and suction pit as illustrated in Figure 3.2.

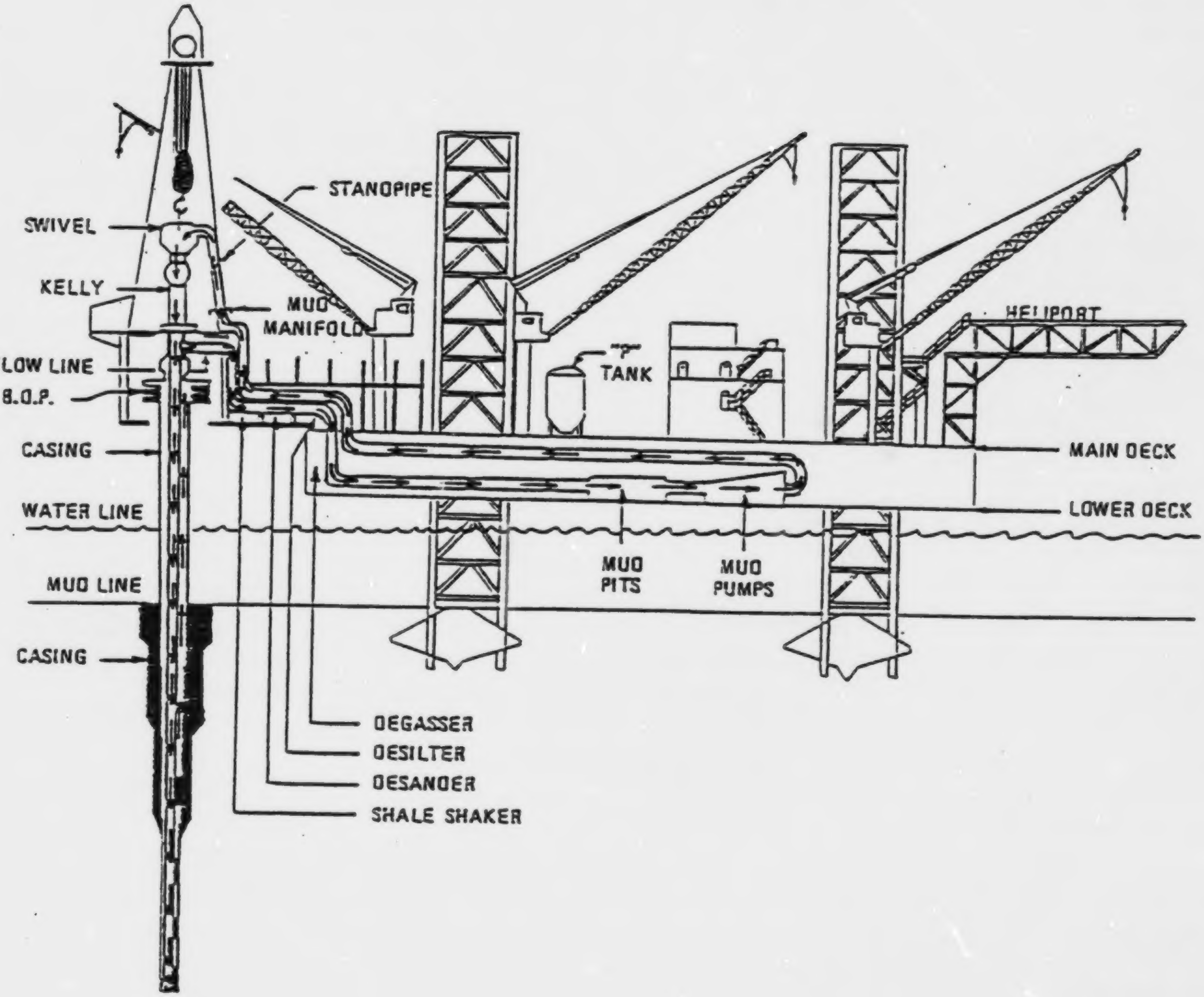

STANDPIPE
SWIVEL
KELLY
MUD MANIFOLD
FLOW LINE
B.O.P.
CASING
WATER LINE
MUD LINE
CASING
"P" TANK
HELIPORT
MAIN DECK
LOWER DECK
MUD PITS
MUD PUMPS
DEGASSER
DESILTER
DESANDER
SHALE SHAKER

FIGURE 3.2: Drilling Fluid Circulation System for a Jackup Rig
(Source: Roughneck Training Manual)

The mud pump is the primary component of any fluid circulation system. The pump is used to provide the pressure to force the drilling fluid up the standpipe, through the mud hose, swivel and kelly and down to the bit through the drill string.

After the drilling fluid has passed through the bit, it returns to the surface via the annulus between the drill string and the well bore, carrying with it the cuttings from the bit. The returning drilling fluid leaves the hole through a steel pipe called the mud return line and falls over a vibrating screening device called a shale shaker.

The shale shaker removes the cuttings from the drilling fluid. After sampling and geological examinations, the cuttings are disposed of and the drilling fluid recirculated. Additional devices, desilters and desanders, are used to remove the silt and sand sized particles from the drilling fluid.

Small amounts of gas in a formation may enter the mud as it is being circulated downhole. This gas is hazardous in the drilling fluid as it reduces the mud density which could produce a "kick". Degassers are used to remove gases from the drilling fluid before the mud enters the mud pit.

The mud pits (tanks) function to accumulate mud circulated through the hole and provide a constant supply of mud to the suction side of the mud pump.

Other components in the mud circulating system include a hopper in which solid materials are added to the drilling fluid. A mud house is used for storing mud materials until needed. Large quantities of material needed in making up the mud may be retained in bulk storage bins.

The total amount of drilling fluid in circulation is dependent upon the depth of the well. For drilling on the Scotian Shelf at 5000 m, total quantitites are in the order of 300 cubic meters.

3.5 Drilling Fluid Selection

Within the context of discussing well site operations, drilling fluid selection and classification, key components of the drilling fluid and major parameters of functions are briefly discussed. A more detailed discussion of this specific function of the drilling fluids is presented in Section 4.

All drilling fluids consist of three components:

- Liquid Phase: with dissolved solids such as alkalies and salts;
- Colloidal Fraction: e.g. bentonite;
- Inert Fraction: e.g. barite;

and are classified as shown in Figure 3.3, on the basis of the principal or continuous component of the fluid phase: water, oil, or pneumatic.

These three major components form the base to which other substances have been added to build a drill mud suitable for particular formation conditions. The density of the drilling fluid is often the most important factor in the selection of a drilling fluid which can vary from the density of air to two and a half times the density of water, as illustrated in Figure 3.4.

Table 3.1 presents the various types of drilling fluids which can be selected. The type of drilling fluid selected for a well will depend upon the expected formation, fluid availability, and cost.

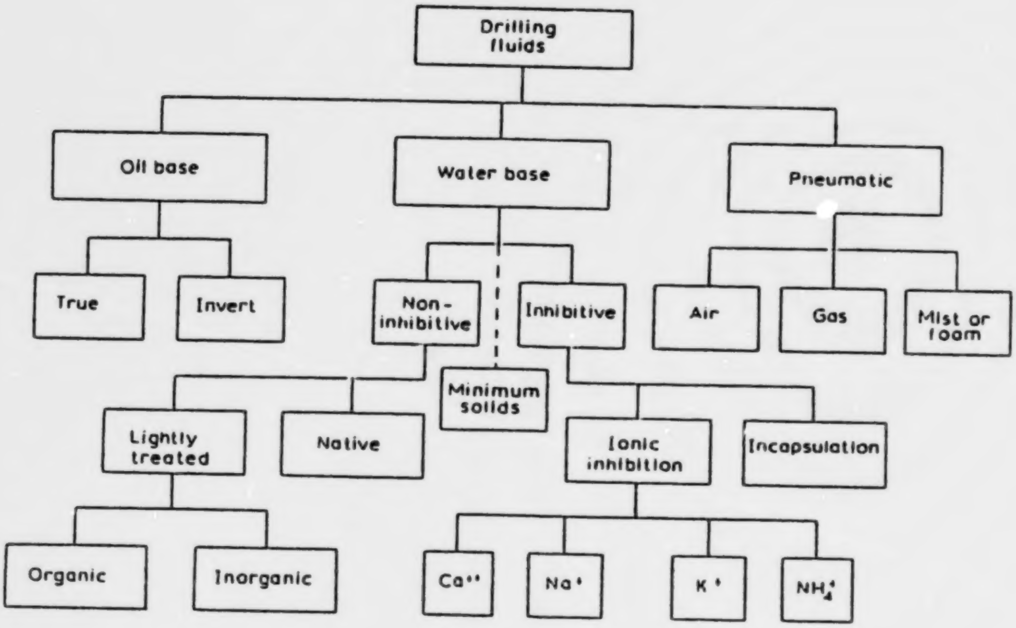

Drilling fluids
Oil base
Water base
Pneumatic
True
Invert
Non-inhibitive
Inhibitive
Air
Gas
Mist or foam
Minimum solids
Lightly treated
Native
Ionic inhibition
Incapsulation
Organic
Inorganic
Ca⁺⁺
Na⁺
K⁺
NH₄⁺

FIGURE 3.3: Classification of Drilling Fluids
(Drilling and Drilling Fluids by
Chilingarian and Vorabutr, 1983)

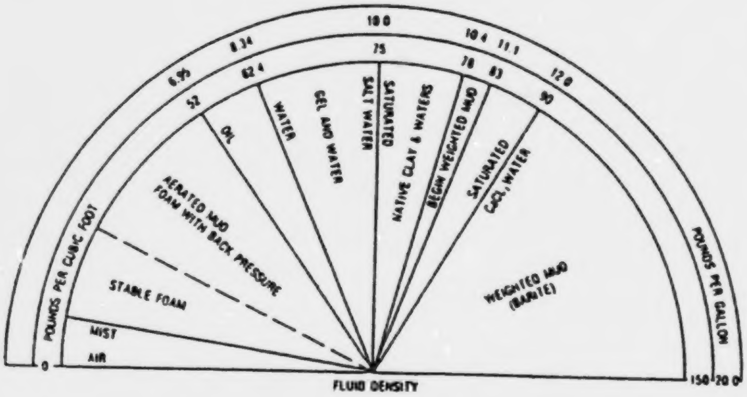


FIGURE 3.4: Ranges in Specific Weigths of Various
Drilling Fluid Types
(Drilling and Drilling Fluids by
(Chilingarian and Vorabutr, 1983)

TABLE 3.1: API Classification of Drilling Fluids

1. Water-Base Drilling Muds

    Fresh-water muds (little or no chemical treatment)

    1. Inhibited muds
    2. Spud muds
    3. Natural muds

    Chemically-treated muds (no calcium compounds added)

    1. Phosphate muds
    2. Organic-treated muds
        (a) Lignite
        (b) Quebracho and other extracts
        (c) Chrome-lignosulfonate

    Calcium-treated muds

    1. Lime
    2. Calcium chloride
    3. Gypsum

    Salt-water muds

    1. Sea-water muds
    2. Saturated salt-water muds

    Oil-emulsion muds (oil-in-water)

    Special muds

    1. Low-solids oil-emulsion muds
    2. Low-clay-solids weighted muds
    3. Surfactant muds
    4. Low-solids muds
        (a) Clear water
        (b) Polymer muds
        (c) Low-solids, non-dispersed muds

2. Oil-Base Drilling Muds

    Oil-base muds
    Invert emulsion muds (water-in-oil)

3. Gaseous Drilling Fluids

    Air or natural gas
    Aerated muds
    Foams

Source: G.V. Chilingarin and P. Vorabutr, Drilling and Drilling Fluids, 1983.

Water Base Drilling Muds

Water base drilling fluids are the most commonly used type throughout the world. The principal component of a water base fluid is water in the continuous phase, along with various materials as additions depending upon required performance. The additions may be industrial minerals, chemicals and organic substances in solution or suspension, as illustrated in Table 3.2.

Fresh Water Mud

Fresh water muds consisting mainly of fresh water and bentonite clay are selected when contamination from beds penetrated is minimal. The most common use of fresh water mud is when spudding in a well and in upper hole drilling.

Calcium Treated Mud

Calcium treated muds are selected when calcium ion (Ca^{++}) contamination is expected, for example, when drilling through salt, gypsum or anhydrite. This causes flocculation of the clay particles, which drastically increases water loss, viscosity and gel strength.

Salt Water Mud

Salt water muds are selected when the fresh water phase of the mud will be contaminated by low concentrations of salt, resulting from salty makeup water, or thin stringers of salt. Saturated salt muds must be used to prevent enlargement of the hole when massive salt beds or dome salt are encountered.

Chemically Treated Water Mud

Chemically treated water muds are selected during drilling formations of low contamination potential to the mud. Chemically treated muds improve drilling efficiency.

TABLE 3.2: Common Drilling Mud Types

Drilling Fluid Type	Major Components	Use Rate in Whole Mud	
		(kg/m^3)	(lb/bbl)
Spud Mud	Attapulgite/bentonite	30 - 140	10 - 50
	Barite	0 - 140	0 - 50
	Lime	1 - 2	0.5 - 1.0
	Caustic (NaOH)	0 - 6	0 - 2
	Soda ash/sodium bicarbonate	0 - 6	0 - 2
	Sea water	as needed	
Saltwater/KCl/ Polymer Mud	Barite	0 - 1280	0 - 450
	Drilled solids	60 - 230	20 - 100
	KCl	15 - 140	5 - 50
	Starch	6 - 35	2 - 12
	Cellulose polymer	0.7 - 15	0.25 - 5
	Caustic (NaOH)	1 - 9	0.5 - 3
	Xanthum gum polymer	0.7 - 6	0.25 - 2
	Sea water	as needed	
Seawater Gel Mud	Drilled solids	60 - 280	20 - 100
	Barite	0 - 140	0 - 50
	Attapulgite/Bentonite	30 - 140	10 - 50
	Caustic (NaOH)	1 - 9	0.5 - 3
	Cellulose polymer	0 - 6	0 - 2
	Lime	0 - 6	0 - 2
	Soda ash/sodium bicarbonate	0 - 6	0 - 2
	Sea water	as needed	
Seawater Lignofonate Mud	Barite	70 - 1280	25 - 450
	Drilled solids	60 - 230	20 - 100
	Attapulgite/Bentonite	30 - 140	10 - 50
	Lignosulfonate	6 - 40	2 - 15
	Lignite	3 - 30	1 - 10
	Caustic (NaOH)	3 - 15	1 - 5
	Cellulose polymer	0.7 - 15	0.25 - 5
	Soda ash/sodium bicarbonate	0 - 6	0 - 2
	Sea water	as needed	
Lightly Treated Lignosulfonate Freshwater/ Seawater Mud	Barite	0 - 500	0 - 180
	Drilled solids	60 - 230	20 - 100
	Bentonite	30 - 140	10 - 50
	Lignosulfonate	3 - 17	2 - 6
	Lignite	0 - 11	0 - 4
	Caustic (NaOH)	3 - 9	1 - 3
	Cellulose polymer	0 - 6	0 - 2
	Lime	0 - 6	0 - 2
	Soda ash/sodium bicarbonate	0 - 6	0 - 2
	Sea water	as needed	
Lignosulfonate Freshwater Mud	Barite	0 - 1280	0 - 450
	Drilled solids	60 - 280	20 - 100
	Bentonite	30 - 140	10 - 50
	Lignosulfonate	11 - 42	4 - 15
	Lignite	6 - 30	2 - 10
	Caustic (NaOH)	6 - 15	2 - 5
	Cellulose polymer	0 - 6	0 - 2
	Lime	0 - 6	0 - 2
	Soda ash/sodium bicarbonate	0 - 6	0 - 2
	Defoamer/detergents	0 - 6	0 - 2
	Freshwater	as needed	
Lime Mud	Barite	70 - 500	25 - 180
	Drilled solids	60 - 280	20 - 100
	Bentonite	30 - 140	10 - 50
	Lime	6 - 60	2 - 20
	Lignosulfonate	6 - 40	2 - 15
	Lignite	0 - 30	0 - 10
	Caustic (NaOH)	3 - 15	1 - 5
	Soda ash/sodium bicarbonate	0 - 6	0 - 2
	Freshwater	as needed	
Nondispersed Mud	Barite	70 - 500	25 - 180
	Drilled solids	60 - 200	20 - 70
	Bentonite	15 - 40	5 - 15
	Acrylic program	1 - 6	0.5 - 2
	Freshwater	as needed	

Source: Thomas et al

Oil in Water Emulsion Mud

Oil in water emulsion muds have been developed to improve the efficiency of drilling, through; increased penetration rates, improved lubrication of bit and drill string, longer bit life and improved down hole conditions such as sloughing shales and bit balling. These muds have been used primarily to decrease drag and torque when drilling directional holes.

Oil Base Drilling Fluids

Oil base drilling fluids which began as specialty fluids when difficult drill conditions were encountered, are gaining greater use because of improved drilling results.

Oil base drilling fluids are an emulsion made up of water in the discontinuous phase, and oil in the continuous phase. Since some water will always be present, the oil must contain water emulsifying agents.

Diesel and paraffin oils are the common oil base formulations. Tables 3.2 and 3.3 list the typical constituents of each respectively.

The paraffin oil base muds perform the same functions as diesel base muds but are considerably less toxic and provide a safer working environment for the rig personnel. A paraffin oil mud contains refined oil which has a portion of its aromatic and napthenic constituents removed.

Pneumatic Drilling Fluids

Due to considerations of formation pressure and hole conditions, pneumatic drilling fluids are not used on the East Coast of Canada and are not considered further in this report.

TABLE 3.3: Typical Diesel Oil Base Mud Formulation and Properties

Properties	
Density	1.5 g/cm^3 (12.5 lb/gal)
Percent oil (vol.)	58
Percent water (vol.)	20
Percent solids (vol.)	22
Oil:Water Ratio	76:24

Composition	Weight Percent	Typical Constituents
Diesel	30	
Water (sea water)	13	
Barite	39	Barium sulphate
Calcium chloride	7	-
Oil stabilizer	3.6	Asphaltene
Emulsifier	0.8	Ethoxylated tall oil resin polyamine
Filtration control agent	3.2	Starch, cellulose
Lime	2.0	-
Clay	1.2	Organophilic (quaternary amine) bentonite

Source: Thomas et al

TABLE 3.4: Composition of a Typical Paraffin Base Mud

		CONCENTRATION
Mud Weight		1.2 g/cm^3 (10 lb/US gal)
Low-aromatic oil (paraffin)		30% (by volume)
Water		29% (by volume)
Barite		27% (by volume)
Sodium chloride		12% (by volume)
Lime		2% (by volume)
Clay	- (Organophilic clay)	
Emulsifier	- (Fatty acid amide)	
Dispersant and oil wetting agent	- (Modified imidazoline)	
High temperature stabilizer	- (Gilsonite (asphaltene))	3% (by volume)
Dispersant	- (Calcium sulphonate)	
Emulsifier component	- (Calcium oxide)	

Source: Thomas et al.

Comparison of Oil Base and Water Base Drilling Fluids

Oil base systems bear little chemical resemblance to water base muds. The oil mud is an emulsion made up of water in the discontinuous phase and oil as the continuous. The essential difference is that the oil in the fluid is not reactive with shale and clay rich formations.

Oil base drilling fluids have the following advantages over water based muds:

- reduced caving and sloughing in the holes;
- reduced hydration and swelling of shales and clays;
- reduced mechanical fracturing of formation;
- good lubrication properties;
- stabilization in salt, potash and anhydrite zones;
- reduced corrosion;
- properties remain stable at greater depths and higher temperatures;
- minimum contamination of potential producing zones;
- resistance to common contamination;
- production testing benefits from lower formation skin damage.

Disadvantages of oil base muds compared to water based are:

- higher cost per unit volume, expensive in lost formation zones;
- solubility of gas in fluid is high;
- more difficult to handle and store.

Shell has converted to "low aromatic content" paraffin oil base muds which have proven cost effective in deep East Coast wells while posing very low levels of toxicity to workers and the environment.

Mobil has indicated that future development drilling on the Hibernia field will be done with water base muds, but for directional drilling, oil base muds will likely be used.

3.6 Quality Control of Drilling Fluids

To maintain the desired properties of the drilling fluid during actual drilling operations, the mud is closely monitored by the Drilling Crew and the Mud Engineer. API Recommended Practice RP 13B "Standard Procedure for Testing Drilling Fluids" (Appendix 4) lists equipment and methods for testing drilling fluids.

Quality control tests generally made by the drilling crew are:

1) Density or mud weight
2) Viscosity and gel properties
   (a) Marsh funnel
   (b) Direct - indicating viscometer
3) Filtration and wall building
   (a) low temperature test
   (b) high temperature test
4) Sand content

Tests generally made by a mud engineer are:

5) Liquid and solids content
   (a) distillation of oil and water
   (b) estimation of composition of properties
6) pH determinations
   (a) colorimetric method
   (b) electrometric method
7) Filtrate analysis
   (a) alkalinity and lime content
   (b) chloride (salt concentration)
   (c) preservative concentration
8) Methylene blue test for cation exchange
9) Hydrogen sulfide
10) Resistivity

How well the fluid composition meets the drilling requirements is determined by its performance in the hole. The mud engineer tests the drilling fluid properties and relates the test results to the performance of the mud. If the fluid fails in some essential function, the composition can be altered to change the properties and improve performance.

Rheology problems and increased viscosity may occur in water base systems due to chemicals and mineral constituents which degrade at great depths under high temperatures and pressures. To maintain desired mud properties, degraded minerals must be removed and replaced by fresh minerals. The replacement of mud constituents results in higher mud maintenance costs. Oil base muds are more stable at great depths so maintenance costs of the mud is low compared to water base muds.

3.7 Casing System and Well Cementing

There are four types of casing used (run) in exploration wells as shown in Figure 3.5.

1) conductor pipe
2) surface pipe
3) intermediate casing
4) production casing

The casing diameter and depth to which each type of casing is set varies with production capacity, pressures, equipment limitation, the ultimate depth and diameter of the well.

The cementing service companies use pneumatic transport equipment for bulk handling of cement. The storage and handling equipment is positioned on the rig making it possible to rapidly mix large quantities of cement at the site.

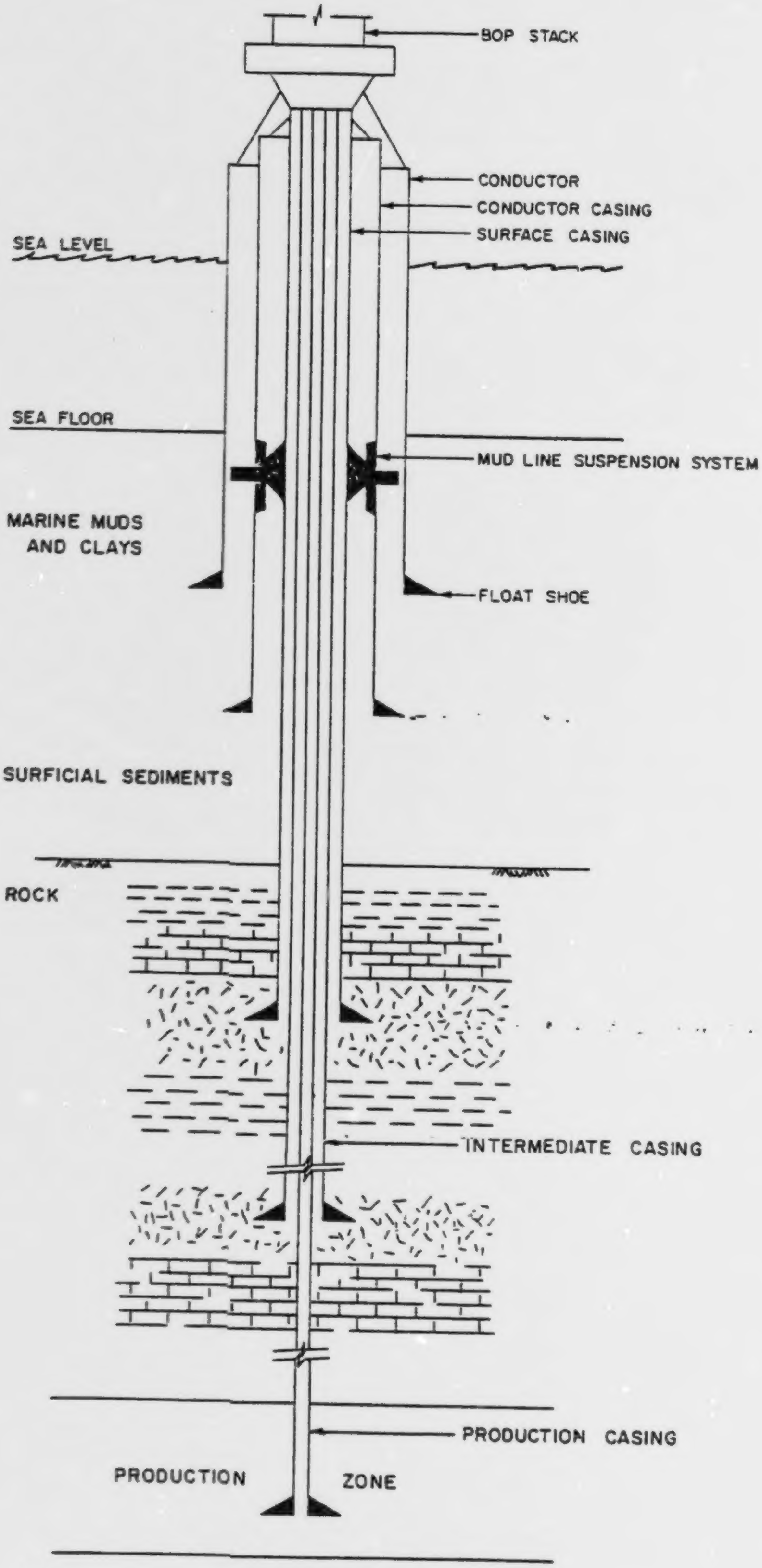

BOP STACK
CONDUCTOR
CONDUCTOR CASING
SURFACE CASING
SEA LEVEL
SEA FLOOR
MUD LINE SUSPENSION SYSTEM
MARINE MUDS AND CLAYS
FLOAT SHOE
SURFICIAL SEDIMENTS
ROCK
INTERMEDIATE CASING
PRODUCTION CASING
PRODUCTION ZONE

Figure 3.5: Schematic of a Typical Casing String

The dry cement is mixed with water in the cement mixing hoppers. The cement slurry is pumped down the casing and up the annular space to bond the casing to the surrounding strata. A special plug is introduced to prevent contamination of the cement slurry by drill mud clinging to the sides of the casing. This plug ruptures when it reaches the guide shoe at the bottom of the casing, allowing the cement to flow up the annulus and fill the annular space. A second plug is sent down to clear out excess cement inside the casing string. The cement is allowed to set for a period of time depending on the type of job, depth, temperature and cement strength.

Oil and gas wells require a cemented casing to:

- support unstable strata
- protect strata from contamination
- support equipment such as Blow-Out Preventors (BOP)
- cut off lost circulation zones
- protect metallic casing from corrosion

Cementing operations are also required to seal "problem formations" during drilling operations and also to seal off productive formations prior to testing. Well abandonment requires significant quantities of cement to leave the well in a safe condition.

4.0 DRILLING FLUIDS

4.1 Functions of Drilling Fluids

The constituents of a drilling fluid must control the conditions encountered down the well bore. The basic functions that must be performed by all drilling fluids are briefly discussed following.

Removal of Cuttings

The removal of the cuttings from the drill bit and bottom of the well bore is one of the most important functions of a drilling fluid. It is achieved by forcing fluid through bit nozzles; thus producing a jetting action which carries the cuttings away from the bit and up the annulus of the well to the surface. Removal of cuttings ensures longer bit life and greater efficiency in drilling.

Cuttings, carried to the surface by circulating fluids, are under the influence of gravity and tend to sink in the ascending fluids. Three factors are important; mud viscosity, density and velocity. The viscosity of the mud is dependent on the concentration, quality and degree of hydration of the suspended solids. A fluid will have better lifting properties when the viscosity is increased. Increasing the density of the mud will increase its carrying capacity due to the increased buoyancy and particle interference. The annular velocity of the mud must be sufficient to overcome the slip velocity of the cuttings being removed. The settling rate of the cuttings is also dependent upon the size, shape and density of the cut particle.

Cooling and Lubricating

The heat generated by the friction on the cutting bit and drill string is conducted away by the drilling fluid when sufficient annular velocity is maintained. The mud itself will lubricate the bit to a certain extent thus decreasing torque, increasing bit life and reducing pump pressure.

Wall Cake

A good drilling fluid should deposit a thin low permeability filter cake in the permeable formations of the well bore to retard the passage of fluids into the formation. The wall cake can be improved by increasing the colloidal fraction of the mud or by the addition of fluid loss control agents such as calcite. The deposition of the filter cake, which reduces the invasion of mud fluid into the formation may also reduce sloughing and caving of shales in troublesome areas.

Control of Subsurface Pressures

The control of formation pressures depends upon the density or weight of the mud. Under normal circumstances, the weight of water and formation solids picked up from drilling are sufficient to balance formation pressures. Higher than normal pressures are sometimes encountered which require the addition of high specific gravity material, such as barite, to increase the hydrostatic head of the mud column. For normal pressures, the density must exceed the normal gradient 10.52 kilopascals per meter. Gradients as low as 9.79 kPa/m or as high as 21.94 kPa/m may be encountered and must be closely maintained to prevent either loss of circulation or a blow-out condition. Mud density is measured with a mud balance and is used in the following formula to calculate the hydrostatic pressure:

Pressure (kPa) = depth (m) x mud density (kg/m^3) x 0.0098.

Suspension and Release of Drill Cuttings

Good drilling fluids must have sufficient thixotropy or gel strength to hold the cuttings being carried to the surface in suspension when circulation is stopped. When circulation is resumed, the mud must possess sufficient fluidity to transport the solids to the surface for separation from the mud in the mechanical solids removal system.

The thixotropic and fluid properties of the mud can be controlled by adjustment of the colloidal content or by chemical additives.

Support of Drill String

As the depth of the well increases, the weight supported by the surface equipment also increases. Since the drill pipe and the casing are buoyed up by a force equal to the weight of the mud displaced, increasing the mud weight will correspondingly reduce the weight supported by the surface equipment.

Preventing Damage to Well Bore

Optimum control of all drilling mud properties must be maintained so that all necessary information for evaluation of a well can be gathered. The mud must not invade the formation, but provide protection and allow maximum production.

Transmission of Hydraulic Power

The carefully designed mud system will automatically aid in transmitting surface horsepower to the bit. A circulation rate sufficient to clean the hole ahead of the bit and maintenance of proper plastic viscosity and yield point benefit hydraulics. The volume and type of mud solids must be carefully monitored.

Corrosion Control

The drill pipe, casing and other metallic components of the drill string can be damaged by corrosion. The extent of this damage can be reduced and the life of metals lengthened by suitable chemical treatments of the mud. Pretreatment for corrosion problems limits the potential for reduced equipment life or loss of well due to equipment failure.

To perform the above functions and also to meet ancillary roles, additives or the ingredients used to formulate drilling fluids can be classified into categories, according to the purpose each serves in the mix, as listed below.

1. Alkalinity and pH control
2. Bactericides
3. Calcium removers
4. Corrosion inhibitors
5. Defoamers
6. Emulsifiers
7. Filtrate reducers
8. Flocculants
9. Foaming agents
10. Lost circulation material
11. Lubricants
12. Shale control inhibitors
13. Surface active agents
14. Thinners, Dispersants
15. Viscosifiers
16. Weighting materials

Many of the properties are attained in the drilling fluid or cement through the addition of specific industrial minerals. Table 4.4 presents a comprehensive list of industrial minerals commonly used in drilling fluids and cement mixes utilized in oil and gas exploration and summarizes the respective functions. A brief discussion of these prime ingredients is provided in Section 4.2.

TABLE 4.4 : INDUSTRIAL MINERALS USED IN DRILLING FLUIDS AND CEMENTS

			DRILLING FLUIDS														CEMENTS							
No.	Industrial Mineral	Chemical Composition or Description	Weighting Agent	Viscosifier	Lubricant	Lost Circulation	Surface Active Agent	Shale Control Inhibitor	Flocculant	Corrosion Inhibitor	Calcium Remover	Alkalinity pH Control	Emulsifiers	Filtrate Reducers	Propping Agents	Dispersants Thinners	Cement	Accelerators	Light Weight Additives	Heavy Weight Additives	Retarders	Lost Circulation	Make Up Dosage	Toxicity T-Toxic P-Potentially toxic N-Nuisance
1	Barite	$BaSO_4$	●																	●			As needed	
1a	Galena	PbS	●																				32 lb/bbl	T
1b	Siderite	$FeCO_3$	●																				As Needed	
1c	Ilmenite	$FeTiO_3$	●																				As Needed	
2	Cement	Synthetic material															●						300 t/hole	N
3	Bentonite	Clay		●															●				5 - 25 lb/bbl or as needed	
4	Sylvite	KCl						●				●											3% - 16% core	P
5	Sodium Carbonate (bicarbonate of soda soda ash, caustic soda)	Na_2CO_3, Trona								●	●	●											0.1 - 2.0 lb/bbl	P
6	Lignite	Brown Coal											●	●		●					●		0.5 - 351 lb/bbl	P
7	Calcium Chloride	$CaCl_2$	●					●										●					10 - 200 lb/bbl	P
8	Halite	NaCl	●			●		●	●					●				●					5 - 125 lb/bbl	P
9	Hematite	Fe_2O_3	●														●						As Needed	
10	Calcite (limestone, quick lime)	$CaCo_3$, CaO	●			●			●			●	●	●			●						50 - 700 lb/bbl	N
11	Gilsonite	Natural bitumens			●		●	●											●			●	As Needed	
12	Mica	Muscovite, Phlogopite				●																	2 - 15 lb/bbl	
13	Sepiolite	Clay		●																				
14	Gypsum	$CaSO_4$ $2H_2O$					●	●									●	●				●	2 - 6 lb/bbl	N
15	Silica Sand	SiO_2				●									●		●							T*
16	Graphite	C			●																		As Needed	P
17	Asbestos	Mg_6 (Si_4O_{10}) $(OH)_8$		●																			2 - 6 lb/bbl	T
18	Diatomite	SiO_2				●													●	●				T*
19	Pozzolan	Volcanic Ash or Fly Ash															●	●	●					
20	Perlite	Volcanic Glass																	●			●		
21	Mineral Wool	Thick silicate fibers				●																		N
22	Witherite	$BaCO_3$	●								●													
23	Cordierite	$(Mg,Fe)_2$ Al_3 $(AlSi_5$ $O_{18})$													●									
24	Smithsonite	$ZnCO_3$								●														
25	Attapulgite	Clay		●																			5 - 30 lb/bbl	P
26	Magnesite	$MgCO_3$ (MgO)										●											0.1 - 0.3 lb/bbl	P

* Dust,Crystalline Form

4.2 The Role of Industrial Minerals in Drilling Fluids

Role of Industrial Minerals

Appendix 3-1 presents an alphabetical list of all drilling muds and additives commonly in use at present. Our study shows that 25% of these contain industrial mineral components for specific purposes as shown in Appendix 3-2 and Table 4.4. The quantitites of the various industrial minerals are presented in Table 7.5 and will be discussed in Section 7.

Our study has shown that over 90% of the mineral useage in either quantity or value is represented by only 11 minerals. These minerals have been selected for detailed discussion in terms of function, use, specifications, etc. as drilling fluid additives. For these minerals, we have also summarized the mineral-logical, mining, and processing aspects in Section 5. The remainder of the minerals, used in lesser quantities are identified and discussed only from the perspective of use. Each industrial mineral used in drilling fluids and how that mineral performs its specific role is discussed in the following sections. Alternate or competing substances are also identified.

Barite

Barite, with a specific gravity of 4.5, is widely used as a weighting agent to increase the specific gravity of drilling fluids. Weighted drill muds are used to control formation pressures and check formation caving. High specific gravity and chemical inertness are of primary importance in selecting a weighting agent. Other factors are: availability, grindability, abrasion, cost and toxicity. The quantity of barite used increases with well depth as shown in Figure 4.1. For example - barite use at 5000 m is in the order of 1300 tonnes.

Other minerals which have been used as a weighting agent are galena, hematite, and ilmenite. Galena, with a specific gravity of 7.4 to 7.6, is a very effective

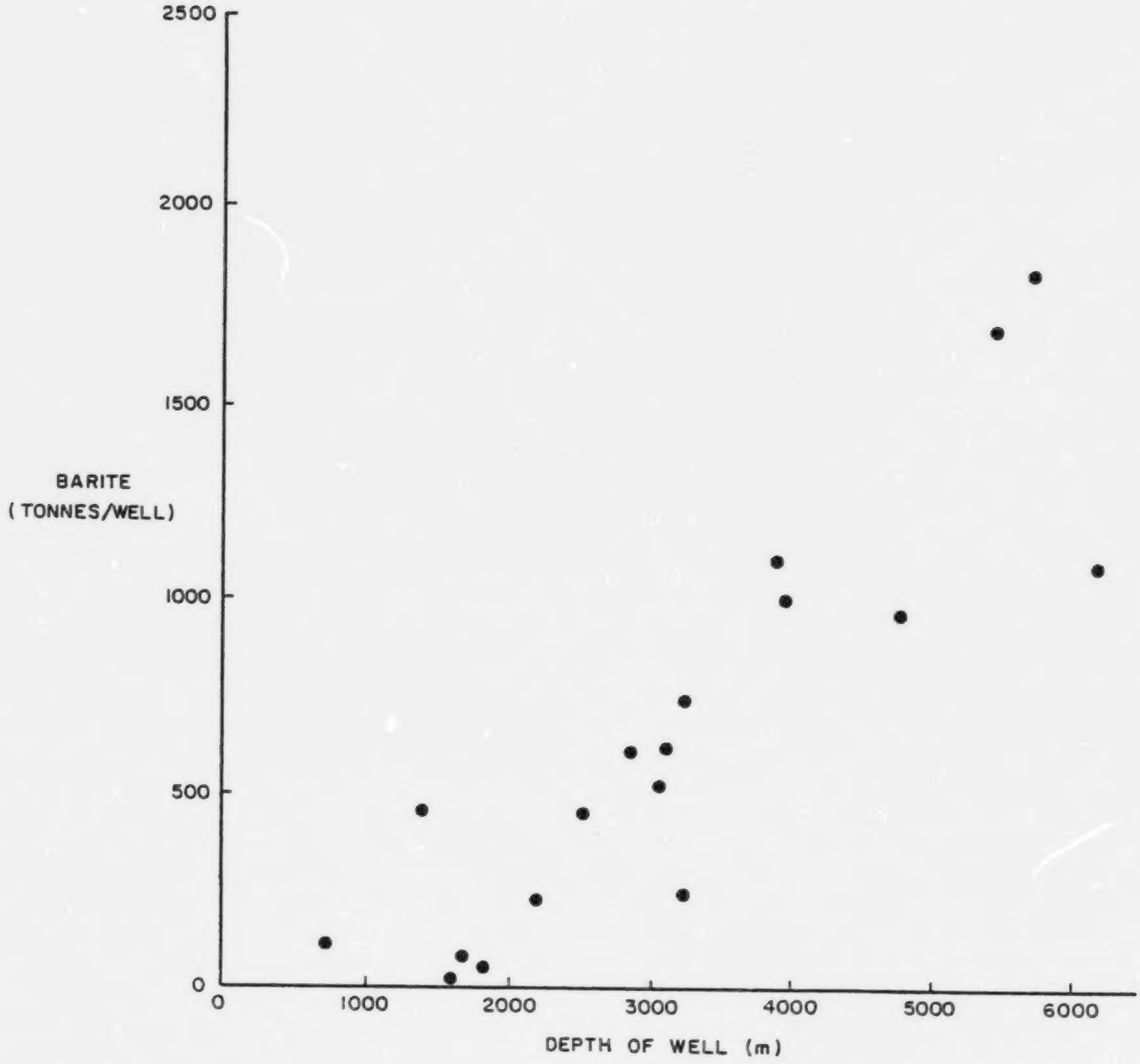


Figure 4.1: Barite Use Versus Well Depth

Source: Thomas et al

weighting agent and is used to control abnormally high pressures. The high cost of this mineral limits its regular use in drilling fluids.

Hematite and ilmenite are also being introduced into drilling fluids as weighting agents. They have a specific gravity of 5.26 and 4.7, respectively, and are promoted on the basis of lower solids content of the drill mud. However, a major concern with hematite and ilmenite is the higher abrasion factor.

Other minerals which are sometimes used as weighting agents are calcite and siderite. These minerals are acid soluble and can be leached from the producing formations thus preserving porosity. Calcite and siderite, with specific gravities of 3.0 and 3.85, respectively, are, therefore, less effective than barite as weighting agents.

Cement

The main function of cement is to seal the annulus between the well casing and the well bore so as to isolate oil and gas producing horizons not only from neighbouring water bearing strata but also to prevent physical communication with the surface. Cement also serves to prevent blow-outs around the casing, protect the casing from corrosion, and to isolate loss-of-circulation zones.

There are no known substitutes for cement. However, the required properties of the cement will dictate the type of cement and additives used.

Bentonite

Bentonite is a colloidal clay consisting primarily of the mineral sodium montmorillonite, that disperses as very small particles in water, easily hydrates to greatly increase drilling fluid viscosity and to reduce filtration. The primary function of bentonite is to suspend drill cuttings in the drill fluid and also to develop wall cake to prevent fluid loss to the formation. The suspending property is needed to assist the passage of cuttings out of the hole and to allow weighting agents to be in stable suspension.

Bentonite exhibits poor dispersibility in saline water, frequently used in offshore drilling operations and also encountered as formation water. Attapulgite and sepiolite are capable of imparting suspension properties in salt water but do not impart good filtration properties to the mud.

The substitution of attapulgite and sepiolite for bentonite has declined as a result of the adoption of ferrochrome - lignosulphonate dispersants which greatly extend the compatibility of bentonites with saline waters.

For use as a gellatant or viscosifying agent for oil based drilling fluids, bentonite is modified with organic amines producing an organophilic clay. The organophilic clays performs basically the same function in oil base muds as bentonite in water base muds.

Sylvite

Sylvite (potash) is the primary source of potassium ions for potassium-polymer muds. Potassium chloride, when added to the drilling fluid, will inhibit the wetting of water sensitive shales and clays.

The use of potassium chloride also helps to lower the freezing point of the drilling fluid. Sylvite is also used for alkalinity and pH control in drilling fluids.

Sodium Carbonate

Sodium carbonate (soda ash) and and its derivatives, caustic soda and sodium bicarbonate, are used extensively for the removal of calcium contamination from the drilling fluids. Soda ash and sodium biacarbonate are added to the drilling fluid to remove the calcium contributed by drilling through gypsum, anhydrite and cement. Caustic soda is also used to restrict the solubility of calcium.

Sodium carbonate, caustic soda and bicarbonate of soda are also used to control alkalinity and pH by the addition of cations to the drilling fluid. Caustic soda is used to: remove carbon dioxide gas and hydrogen sulfide gas; to control corrosion; and to solubilize lignite, lignosulfonate and other tannin substances.

Chrome Lignite and Lignite

Lignite is used as a dispersant and a thinner in colloidal suspensions of bentonite. Bentonite particles carry electrochemical charges, causing a tendency for the particles to agglomerate. Lignite has soluble amine acids which neutralize the attractive forces in the clay particles, thus helping them disperse in suspensions.

As a thinner, lignite and chrome lignite have a higher temperature stability than other chemical thinners, and are preferred for relatively high temperature - deep hole drilling programs. Since lignite is only partly soluble, it is used as a fluid loss inhibitor. Lignite is often modified by reaction with caustic soda, iron and chromium chemicals for enhanced dispersant properties.

Lignite derivatives are also used in oil based muds to reduce filtration, and in oil invert muds to improve the stability of water in oil emulsions.

Calcium Chloride

Calcium chloride is used in hole-stabilization of both water and oil muds; in calcium treated muds; in preparation of dense salt solutions for completion, workover, and for lowering the freezing point of water base muds. It is also useful as an accelerator in cements.

Halite

Halite or rock salt is used primarily as a weighting agent to increase the density of the drilling fluid and as a hole stabilizer to retard dissolution of salt beds. Salt is also used as a loss of circulation agent in workover and completion fluids by adding graded salt particles to saturated brines, and also to lower the freezing point of drilling fluids.

In some cases, salt is used as a flocculant to settle suspensions by increasing the effective radius of particles in suspension through the formation of large, combined particle groups, called "flocs". These "flocs" in turn settle out rapidly making it possible to re-use the clear top portion of the fluid in drilling.

Salt is also used as a shale stabilizer; to control caving by retarding the hydration of shales, and as a filtrate reducer when building wall cake to avoid formation damages.

Hematite

Hematite with a high specific gravity of 5.26 is used as a weighting agent, particularly in over pressured zones, i.e. when the mud weight desired is 15 lb/gal. or greater.

Hematite is much more abrasive and expensive than barite. Therefore, barite is preferred for normal weighting up to about 15 lb. per gallon.

Calcite

Calcite is used as a weighting agent, usually in the crystalline white marble form in both fresh water or brine fluids and oil base muds. In oil base fluids it is also used to provide wall cake build-up in acid soluble fluid systems. It can be used as a bridging agent for formations having pore dimensions up to 15 microns.

Calcite has two derivatives, quicklime and hydrated lime, both of which are widely used in the drilling industry. Hydrated lime is used for pH control and to suppress the solubility of calcium in water based drill fluids. Quicklime is used in oil muds for the formation of calcium soaps and for the removal of water. Sized calcium carbonate is used as a lost circulation material.

Calcite, in the form of chalk, is used as an emulsifier.

Gilsonite

Gilsonite is used as a lubricant in drilling fluids, and is added to create suspension properties in oil base muds. Gilsonite is also used as a hole stabilizer when steeply dipping shales are encountered.

In cements, gilsonite is used to prepare cement slurries of low density and superior lost circulation control characteristics.

Mica

Mica is often used to stop loss of circulation by plugging formation pores. The long, stable mica flakes are effective for lining the well bore in loss-of-circulations zones and, therefore, encourage filter cake formation.

Sepiolite

Sepiolite is used as a viscosifier in salt water muds, in which bentonite exhibits poor dispersibility.

Gypsum

Gypsum is occasionally added to increase the calcium ion concentration in muds, thereby flocculating the clay minerals and thinning the drilling fluid.

Gypsum is also effective as a shale control inhibitor.

Silica Sand

Silica sand is a common additive in cement, as a loss of circulation material and as propping agent in well stimulation.

The following minerals have lower reported usage, however, are included for completeness. These minerals, although used less frequently, do provide specific and necessary characteristics.

Graphite

Graphite has been used essentially as a lubricant, especially where a drilling fluid entirely free of deliberately added oil is required. The lubrication properties of graphite are well known.

Asbestos

Fibrous asbestos has been added to water in "lean drilling fluids" for improvement in cuttings recovery. Asbestos is used when the only requirement for the drilling fluid is to improve cuttings recovery at the surface for geologic examination.

Diatomite

Diatomite has been used in drilling fluids as a lost circulation material. It is also used in cements to reduce slurry density since its use requires increased mixing water.

Pozzolans

Pozzolans are siliceous materials available naturally or derived from fly ash produced by burning coal. They are useful in producing lightweight cements used in offshore well cementing. The advantages of using pozzolans in cement are: economic savings, resistance to corrosion, low heat of hydration, low water solids ratio, low permeability, and improved pumpability.

Perlite

Perlite is composed primarily of volcanic glass which is rhyolitic in composition. Granular perlite is added to Portland cement to obtain slurries having low density and excellent bridging properties for lost circulation control.

Mineral Wool

Mineral wool, consisting of thin silicate fibers has been used in drilling muds as a lost circulation material.

Witherite

Witherite has been used as a weighting agent in drilling fluids. Witherite has also been used as a calcium remover.

Cordierite

Cordierite is used in exploration drilling as a propping agent to provide channels for fluids to flow in producing formations.

Smithsonite

Smithsonite is used in drill muds as a corrosion inhibitor.

Attapulgite

Attapulgite is used as a viscosifier in salt water muds.

Magnesite

Magnesia, a product of magnesite calcination, is used as an alkalinity pH control.

5.0 INDUSTRIAL MINERALS DETAILED DISCUSSION

This section of the report provides detailed information on the industrial minerals most commonly used on the offshore. The items addressed include functions, use, mineralogy, mining and beneficiation techniques. Brief summaries of the API specifications (Appendix 4) are presented where available. Table 5.1 (located at the end of this Section) summarizes major aspects of industrial mineral usage in the offshore drilling industry.

Specifications for materials not evaluated by API are defined by the purchaser and may vary widely.

The minerals are presented ranked by current dollar value, based upon data collected during this study. However, market conditions are very volatile for many of these products and are, therefore, subject to change. Although the API specifications are the standard, lower grade materials may be accepted for price considerations.

While the researchers made every effort to assemble all data available, in some cases the data base was incomplete, or inconsistent and, therefore, data gaps exist in the presentation. The presentation of technical detail is weighted in favour of those minerals which exhibit high usage and value, or known to have the potential of being produced within the Atlantic Region.

5.1 Barite

The mineral barite, natural barium sulfate ($BaSO_4$), is the most common mineral containing barium.

Barite is the most widely used weighting agent in drilling fluids due to its inherent properties and characteristics:

- high specific gravity (4.3 - 4.5)
- color, white to brown
- chemically inert, insoluble in water and weak acids

- widely distributed, high availability
- brittle and easily ground to desirable particle size
- relatively non-abrasive, hardness 3.0 - 3.5 (MOHS)
- low toxicity.

Geology

In most commercial deposits, barite occurs as concretions, nodules, rosettes, irregular masses and in laminated to massive beds of fine crystallinity. Barite occurs as a major mineral in veins and beds and is often associated with one or more other minerals such as fluorite, celestite, quartz, calcite, dolomite, siderite, hematite and stibnite. Barite has been found in all geological environments and deposits are normally classified into three main categories; vein-and-cavity filling, residual and bedded.

Vein-and-cavity filling deposits are those in which barite and associated minerals occur along faults, gashes, joints, bedding planes, breccia zones, solution channels and sink structures. These deposits may occur in almost any kind of host rock and range in age from Precambrian to Tertiary. These types of deposits are known at Brookfield and Scottsville in Nova Scotia and also at Collier's Point and Buchans in Newfoundland.

Residual barite deposits occur in unconsolidated material formed by the weathering of pre-existing deposits, often from Cambrian and Ordovician limestone and dolomite and are common in the American mid-western states.

Bedded deposits include those in which barite occurs as a principal mineral or cementing agent in strataform bodies in layers of sedimentary sequences. The beds of barite may range from several centimeters to 15 meters, or more, in thickness and may extend over large areas. These deposits may be large and single deposits can contain millions of tonnes of easily beneficiated barite.

The Pine Brook deposit in Nova Scotia is an example of a bedded barite deposit.

Mining

Barite is mined by both underground or open pit methods. The method is dictated by the characteristics of the deposit.

Present barite mining ventures in Nova Scotia have been small scale surface operations, typically employing selective extraction methods on a seasonal basis. This approach is particularly suited to Nova Scotia based demand for barite to feed locally operated grinding (usually small and often portable) mills.

Mining activity in Newfoundland has been minimal. An underground operation located at Collier's Point, operated as a joint venture, had limited success.

Beneficiation

Barite ores generally require upgrading to meet API specific gravity specifications for use in drilling fluids. The composition of the barite ore, gangue and associated physical, chemical and mechanical properties, determine the type and level of processing used for beneficiation. All natural barite requires grinding to meet the size specifications.

The specifications for barite used as a weighting agent in drilling fluids are established by API and are summarized as follows:

Specific Gravity	- 4.2
Wet Screen Analysis	
Residue on No. 200 Sieve (75 micrometers)	- 2.5% max.
Residue on No. 325 Sieve (45 micrometers)	- 15% max.
	- 5% min.
pH	- 8.5 max.
	- 6.5 min.
Water Soluble Solids	- 0.1 % max.

Beneficiation of barite ores is generally carried out by one, or a combination, of the following methods:

- Dense Media Separation
- Flotation
- Cyclones
- Sluices, Shaking Tables
- Jigs

World Production

Total world production of barite amounts to about 7 or 8 million tonnes annually. The United States, China and the Soviet Union are the major producers; yet small countries like Ireland, Morocco, Peru and Thailand produce significant quantitites. The major consumers are the United States, the Soviet Union, West Germany and Mexico. Recent fluctuations in barite consumption, of 1 million tonnes annually, have been caused by sudden changes in well drilling activity.

Canada is not a major producer of barite. Total Canadian production reported in 1983 amounted to 28,000 tonnes which is less than 1% of the world total. Canadian production of mud grade barite is derived from deposits in British Columbia, Yukon Territories, Nova Scotia, and Newfoundland.

More than 2 million tonnes of barite ore, grading between 5% and 40% has recently been found associated with the large, newly discovered gold deposits at Hemlo, Ontario.

In recent years, within Atlantic Canada, limited barite production has been derived from deposits located at Brookfield, Bass River, Pine Brook and tailings recovery at Walton in Nova Scotia and from Collier's Point and Buchans in Newfoundland. Production from these local sources have been supplemented by barite imported from Ireland and Morocco.

5.2 Cement

Cement has long been considered an industrial mineral and is defined by API as "the product obtained by grinding clinker, consisting essentially of hydraulic calcium silicates, to which no additions other than suitable set-modifying agents have been interground or blended during manufacture."

The specifications for well cements are stringently defined by API to include 9 categories (A to J) classified according to intended use and operating conditions, such as heat and pressure. For detail concerning the chemical and physical requirements of the cements, the reader is referred to API Spec 10. The additives and varieties of cements serve to modify the cement thickening time, set time and strength characteristics.

Raw Materials

The primary requirement for all cements is a source of lime (CaO) generally obtained from calcite; found naturally as limestone or marble. Other required raw materials include silica and alumina, usually obtained from sand, silt or clays. Gypsum is often used as a source of SO_3 Which provides some control of the setting time.

Cement Manufacture

The raw materials are processed into cement clinker and ground in standard manufacturing plants.

Final production of oil well cements is performed by carefully proportioning clinker feed with other additives in small quantities in the grinding mills.

In Canada, at 1984 year end, there were a total of 9 companies producing approximately 91 million tonnes of cement. In the Atlantic Region two companies were producing cement, Canada Cement Lafarge Limited in Brookfield, Nova Scotia and Havelock, New Brunswick, and North Star Cement Limited in Corner Brook, Newfoundland. The total clinker capacity of these three plants is 878,000 tonnes per year.

Substitution

There is no known substitute for cements used in oil well drilling.

5.3 Bentonite

The generic term bentonite includes several species of clay minerals, consisting essentially of the smectite group. These minerals have vast electrically charged surface areas which attract certain metallic ions. The type and ratios of these ions determines the potential uses. Drilling mud bentonite requires a high ratio of sodium to calcium ions.

In well drilling, both natural and synthetic bentonites are used to increase the suspension properties of water base muds and for the formation of mud cake on the hole wall. Natural bentonites in use are predominantely Wyoming sodium montmorillonite. Hectorite is a rare type of bentonite, finding use in oil well drilling fluids due to its high viscosity properties, higher thermal stability and better tolerance to electrolytes. Hectorite is a lithium-magnesium smectite which is found naturally in California and is manufactured synthetically in Texas.

Geology

Bentonite is found in deposits of Cretaceous age; occurring in beds or lenticular bodies that are stratigraphically controlled. Bedded deposits ordinarily have a characteristic sharp contact with underlying rocks and a gradational one with the overlying strata. Bentonite deposits are believed to have been formed from volcanic ash deposited in shallow seas of relatively flat terrain and alkaline lakes.

Bentonite has also been formed by hydrothermal activity, which forms irregular shaped bodies rather than beds. Opinions differ concerning the process and time of alteration of the ash, although most authorities agree the change in ash would have begun with its contact with water.

Mining

Almost all bentonite is mined by typical surface methods. Mineable ore thickness averages 0.75 meters and overburden ratios of 10 to 1 are not uncommon.

The grade of bentonite can be highly variable within a deposit, requiring selective mining and stockpile blending to produce desired grade.

Beneficiation

Bentonite processing entails drying to remove moisture and volatile materials and final grinding. The bentonite is allowed to air dry prior to mechanical drying in oil, gas or coal fired rotary kilns. The drying process must be carefully controlled to produce bentonite of drill mud grade. The swelling properties of the bentonite can be greatly reduced if the clay is over heated. The final product clay is ground and sized prior to shipment in bag, barrell or bulk format.

The API specifications for mud grade bentonite are summarized as follows:

Suspension Properties	
Viscometer Dial Reading at 600 rpm	30, minimum
Yield Point, lb. per 100 ft.^{2}	3 x Plastic Viscosity, max.
Filtrate, relative 30 minute	15.0 cm^3. max.
Wet Screen Analysis	
Residue on U.S. Sieve No. 200 (75 micrometers)	4.0 wt% maximum
Moisture, as shipped from point of manufacture	10 wt% maximum

World Production

The United States is the largest producer of Bentonite, however, good quality bentonite is produced in Cyprus, Greece, Italy, Canada, Yugoslavia, Morocco, United Kingdom and Germany. Not all of the above countries derive their bentonite from natural sodium clays. Some suppliers treat calcium montmorillonites with a base exchanging agent such as soda ash to add sodium ions and improve characteristics.

5.4 Sylvite (Potash)

Potash is a generic term for a variety of potassium bearing minerals and refined products. The major use (90%) is in the fertilizer industry. Other uses are chemical applications such as in the petroleum exploration industry.

Geology

Potassium is the seventh most abundant element in the earth's crust and is present in igneous, metamorphic an sedimentary rocks as silicate minerals. Potash deposit of economic value are typically restricted to large marine evaporite deposits.

Two ages of potash deposits have been reported:

(1) Paleozic age deposits, which were formed in cratoni basins and characterized by mineral assemblages containing sylvite and potassium sulfate-bearing phases.

(2) Triassic age deposits, formed in the continental margin rift systems, are characterized by primary carnallite bearing assemblages.

Marine evaporite deposits are characterized by sequence of tabular beds which vary in mineral composition, as well as texture, color and grain size. The thickness of these beds can range from a few centimeters to several meters.

Potash is usually mined by underground room and pillar methods using continuous mining machines. Extraction ratios vary from 50% to 85% of the total beds available. Solution mining is applicable to soluble potassium minerals, such as thick high grade sylvite ores in Saskatchewan and Utah.

Beneficiation

Potash ores are typically concentrated by one of three methods:

- selective flotation;
- selective dissolution of the gangue mineral; and
- precipitation of the potash mineral from a hot brine.

Selective dissolution is performed by dissolving or washing the readily soluble halite gangue and concentrating the sylvite.

Precipitation from a hot brine is accomplished by selectively dissolving the potassium minerals in a sodium chloride brine, de-sliming and precipitating a pure sylvite product by controlling the composition and temperature of the brine.

World Production

More than 90% of the market for potash products are tied into the agricultural industry, a relatively stable market. Drill mud products are derived from this primary production.

At the end of 1983, Canadian production capacity was 9 million tonnes in Saskatchewan and a nominal 100,000 tonnes in New Brunswick. In New Brunswick, the Potash Company of America (PCA) and the Denison-Potacan Potash Company are in operation.

Canada is ranked second behind the USSR in potash production.

5.5 Sodium Carbonate

Sodium carbonate is an industrial mineral which is obtained from natural trona deposits and synthetically from the Solvay process. Sodium bicarbonate and caustic soda are chemicals which are derived from sodium carbonate (Figure 5.1).

Anhydrous sodium carbonate does not commonly occur naturally. Natron, thermonatrite, and trona minerals have been used directly as sources of sodium carbonate. These minerals occur in non-marine alkali lakes and marshes. Numerous occurrences of sodium carbonate are known in the world.

Mining

Sodium carbonate is mined by the underground room and pillar method, by solution mining or dredged from shallow alkali lakes. Underground trona mines are operated in the central U.S.

Beneficiation

Sodium carbonate obtained from trona deposits are processed by the Wyoming Trona process. The trona is dissolved and separated from the impurities (solids and organic matter) by classification. The dissolved trona is precipitated and calcined to produce soda ash.

Sodium carbonate is also produced by the Solvay process in which sodium chloride is saturated with ammonia gas and the resulting brine carbonated using CO_2 to manufacture sodium bicarbonate. The sodium biacarbonate is calcined to drive off H_2O, NH_3 and CO_2 thus producing a light soda ash.

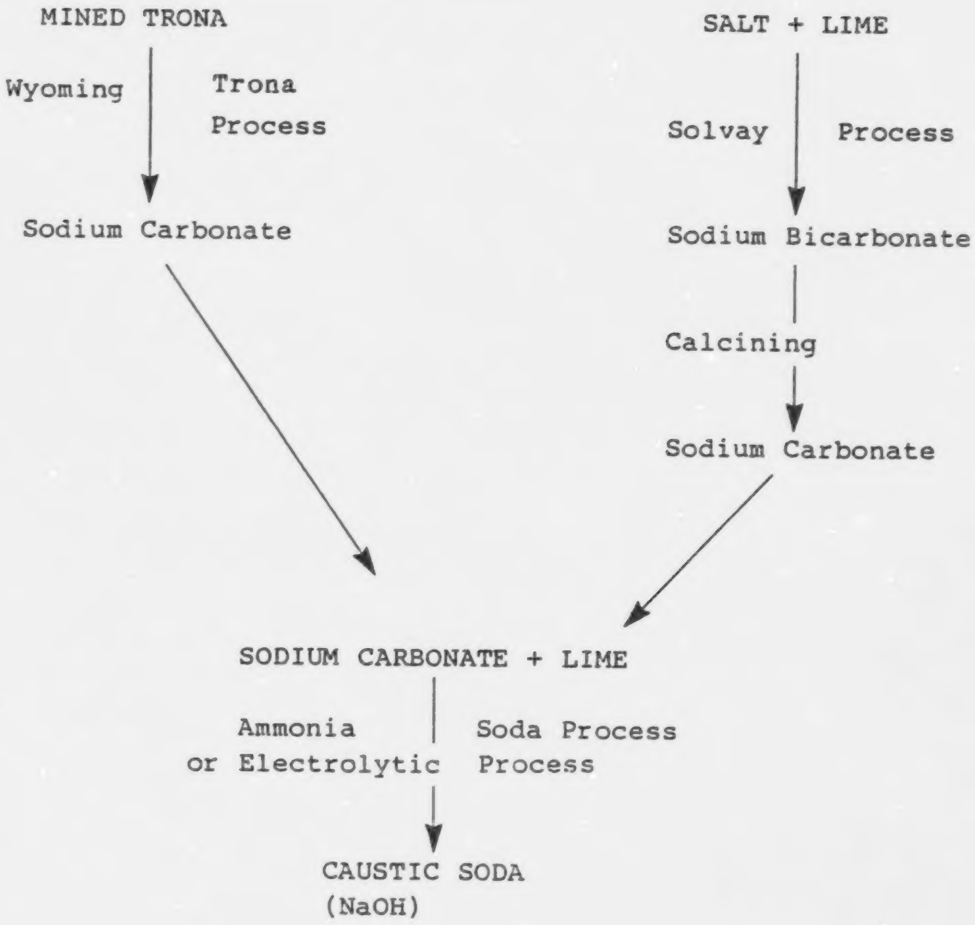

MINED TRONA
Wyoming
Trona Process
Sodium Carbonate
SALT + LIME
Solvay
Process
Sodium Bicarbonate
Calcining
Sodium Carbonate
SODIUM CARBONATE + LIME
Ammonia or Electrolytic Process
Soda Process
CAUSTIC SODA (NaOH)

FIGURE 5.1: Sodium Carbonate and Derivatives

In Canada, Allied Chemical operates a Solvay process plant at Amherstberg, Ontario, with a capacity of 400,000 tonnes per year.

There are no producers of sodium carbonate in Nova Scotia. However, salt and limestone are abundant, therefore offering potential for the development of a Solvay type process plant.

5.6 Lignite

Lignite is a low rank brownish black coal which is intermediate between peat and sub-bituminous coal. It commonly retains the structures of the original wood, is high in moisture, low in heat value and decomposes upon dehydration.

Geology

Lignite occurs as a sedimentary deposit with alternating bands of sandstone, shale and clay, usually in a fresh water environment. The beds, or seams, generally form large flat lenses. Seam thicknesses range up to 30 meters.

Mining

Lignite is normally mined by both open pit and underground methods using standard equipment. The mines are frequently large scale to produce this relatively low value product.

Beneficiation

Lignite coals are processed by grinding to liberate the coal from stone inclusions, screened to size consistency and dryed to remove excessive water content prior to shipping.

5.7 Calcium Chloride

Calcium chloride is a deliquescent salt; the main source of which is as a by-product of the Solvay process employed for making soda ash (the reader should refer to Section 5.5 for a more detailed discussion of this process). It is also found occuring naturally in brine wells, and dry lake beds. It has been included in this study as it is used as a weighting agent, a shale control inhibitor and as an accelerator in cement. Calcium chloride could be produced locally if a sodium carbonate (soda ash) plant was established.

The product is normally stored in air tight containers due to its deliquescent nature.

5.8 Halite (Rock Salt)

Geology

The mineral halite, or common salt, is deposited in sedimentary beds and salt domes formed by the evaporation of saline waters which also resulted in deposition of gypsum, anhydrite, and potash.

Bedded deposits are generally lenticular ranging in thickness from a few centimeters to several meters and are of Silurian, Permian and Triassic age. Salt deposits in some areas has been folded into diapir structure or domes which frequently also contain hydrocarbon accumulations of economic worth.

Mining

Halite is mined by solution mining or conventional and continuous underground methods. All halite deposits generally should be 95 percent sodium chloride to be economically viable.

Beneficiation

Rock salt which is mined dry is crushed and screened and further upgrading, if required, may be conducted using the Sortex process and/or Thermoadhesion process to increase the halite content from 97% to 99%. Pure grades can be produced from the recrystallization of fine crystal rock salt achieving 99.99% NaCl.

Production

The major salt producing countries of the world are the United States, China, USSR, Germany, India, U.K., France and Canada. World production totalled 190 million tonnes in 1984.

Two mines in Nova Scotia have a production capacity of more than 1.0 million tonnes per annum. The Canadian Salt Company Limited produces rock salt from an underground mine in Pugwash, Nova Scotia; used mainly for de-icing highways. The Sifto Salt Division, Domtar Chemicals Group produces process salt from an underground brining operation at Nappan, Nova Scotia.

5.9 Hematite

Hematite, Fe_2O_3 (70 percent iron and 30 percent oxygen) is the most abundant iron ore mineral. It has a specific gravity of 5.26, a hardness of 5.5 to 6.5 and has been used as a weighting agent in drilling fluids as a substitute for barite when dense muds are required. The common form of hematite being used is micaceous hematite, which also promotes bit lubrication and is less abrasive.

Geology

Hematite is widely distributed and occurs in sedimentary, metamorphic and igneous rocks. Deposits of major economic importance occur as irregular masses or beds. The deposits often contain millions of tonnes of high purity ore.

Mining

Hematite is typicaly mined by open pit methods such as those applied in the operations located in Labrador and Brazil. The Brazilian deposits report high grades and have been supplying drilling grade product.

Beneficiation

At the Germano Mine in Brazil, the ore is ground in ball mills and the hematite and quartz are separated through cationic flotation, producing a premium grade micaceous hematite concentrate.

API specifications for hematite are not currently available. However, the Brazilian product is being supplied as a weighting agent at the following standards:

Minus 100 mesh - 100%
Minus 200 mesh - 98.5% - 99.8%
Minus 325 mesh - 92.5% - 96.0%

Free Moisture @ 105°C - Less than 0.5%
Specific Gravity - 5.1
Iron Content - 68.0% - 68.5%

5.10 Limestone

Geology

Carbonate rich rocks or limestones have been deposited from Precambrian to recent times. The deposits are frequently chemical or biochemical precipitates and are formed in place. Most limestone deposits of economic importance were derived from seawater which accumulated in shallow marine deposits.

Environments of deposition determine the size, shape, purity and other economically significant characteristics of the carbonate rocks. The essential minerals of limestone are calcite, aragonite and dolomite.

However, some limestone contains minor ankerite, siderite and magnesite. Common impurities are clay, chert and organic matter.

Mining

Most limestones are mined primarily by open pit methods, using conventional techniques. Production in Eastern Canada is entirely by open pit methods.

Beneficiation

The raw limestone must normally meet product quality requirements for calcium content so processing is restricted to size classification and drying. Larger size fractions are sold and shipped by bulk transport while finer size fractions are either bagged or transported in bulk.

The limestone is not used directly within the mud, but rather as derivatives such as lime and calcium hydroxide. Specifications for these purposes are usually stated as high quality Ca content. Industrial grade chemical derivatives are used by the drilling industry.

5.11 Lime

Lime is made by calcining and buring high calcium or high magnesium (97% combined carbonate content minimum) limestone; producing what is commonly known as quick lime, calcium oxide or calcia. The addition of water to quick lime produces calcium hydroxide or slaked lime.

World Production

There is little foreign trade for lime as most countries have sufficient occurences of limestone suitable for the production of lime.

5.12 Gilsonite

Gilsonite, a common asphalite, is a naturally occurring solid bitumen. It is generally dark colored, brittle, breaks with conchoidal fracture, and has a low specific gravity.

Geology

Gilsonte is found in Colorado, occuring in a long nearly vertical, narrow fissure, many kilometers long and up to 6.0 meters wide.

Mining

Gilsonite is mined hydraulically, using either high pressure water jets or water flooded rotary cutters.

The slurry is pumped to a preparation plant where three grades of product are produced: ordinary, selects and screened selects. The three grades of product are defined by melting point, fracture, and degree of fines.

5.13 Mica

The mica group of minerals are characterized by a sheet like nature. This platy mineral occurs in a variety of complex hydrous aluminosilicate forms with differing chemical composition and physical properties. Principal minerals in the mica group include:

Muscovite - potassium mica
Phlogopite - magnesium mica
Biotite - magnesium - iron mica
Lepidolite - lithium mica

Mica is useful to the oil industry because of its long stable sheets (books) which are used to stop lost circulation to porous formations.

Geology

Muscovite and phlogopite are commonly found in regionally metamorphosed rocks. Granitic pegmatites are the major commercial source of muscovite sheets. Phlogopite sheets are found in areas of metamorphosed sedimentary rocks into which pegmatite-rich granite rocks have intruded. Micas of pegmatitic origin normally occur as dikes or sills, some of which have been known to exceed 60 m in thickness and 300 m in length.

Mining

Mica flakes are recovered primarily from pegmatite residual deposits formed by the weathering of mica-bearing rocks. Mining of mica flake is amenable to conventional techniques. Most deposits are mined by open pit, however, some can be mined by hydraulic methods.

Beneficiation

Raw mica is processed so as to render the product to size and quality specifications. Several processing techniques are employed to upgrade the mica after grinding and screening the raw feed:

- gravity separation - Humphrey spiral
- flotation
- cycloning

World Production

There are many world producers of mica, the largest of which is the United States with a 1983 production of 115,000 tonnes. Other producing nations, in order of yearly output include: USSR, India, Korean Republic, and Canada.

5.14 Toxicity

The majority of the industrial minerals used in association with drilling fluids are not considered to be particularly hazardous. The American Conference of Government Industrial Hygienists (ACGIH) Handbook has identified both asbestos and diatomaceous earth as potentially carcinogenic. The dusts of industrial minerals such as calcite, cement, gypsum and mineral wools are classified as nuisance particulates. Potential toxic hazards are flagged on Table 4.4.

TABLE 5.1: INDUSTRIAL MINERALS DATA SHEET

MINERAL COMPONENT	QUANTITY USED (1) VALUE (2) (per well)	KEY SPEC. SOURCE	PROCESSING	PACKAGING & TRANSPORT	SOURCE			SUBSTITUTE
					ATLANTIC CANADA	CANADA	FOREIGN	
BARITE $BaSO_4$	1,100t $185/t	S.G. 4.2 3% max on 200 mesh 5% min on 325 mesh Solubles, 200 ppm max. API Spec 13A	-crush -grind -gravity separation -flotation -final grind	100 lb-s bulk-p -pn	X	X	X	-Hematite -Ilmenite -Galena -Siderite
CEMENT Synthetic, calcium silicates, raw materials, lime, silica, alumina	370t $200/t	Classes A - J API Spec 10	Primary and secondary grind tertiary, dry or wet mill. Pyro-process clinker product milled	100 lb-s bulk -p -pn	X	X	X	None
BENTONITE CLAY	230t $286/t	Plastic Viscosity 15.0 cp min. Filter Loss 14 ml.max Wet screen analysis 200 mesh residue 2.5% max Moisture content 12% max API Spec 13A	Crush, dry finely milled in roller mills	50 - 100 lb-s -s -b bulk-pn		X	X	-Attapul-gite -Sepiolite
SYLVITE KCl	175t $440/t		-Flotation -Selective dis-solution of gange -precipitation	50 to 100 lb-s	X	X	X	
SODIUM CARBONATE 1 bicarbonate of soda 2 soda ash 3 caustic soda	Total of 3 24t $1.01/kg $1.45/kg $0.47/kg		-Wyoming Trona Process -Solvay Process -Calcine =Sodium Carbonate (Soda Ash) -Ammonia Soda Process -Electrolytic Process =Caustic Soda (NaOH)	50 to 100 lb-s	P	X	X	
LIGNITE -Chrome Lignite -Lignite BROWN COAL	Combined Total 138t $1.16/kg $0.47/kg		-crush, grind -gravity separation -flotation -chemical treatment of lignite to produce chrome lignite	50 lb-s	P?	X	X	
CALCIUM CHLORIDE $CaCl_2$	18t $0.87/kg		-Solution mined -Byproduct of Solvay Process	80 or 100 lb-s		X	X	
HALITE NaCl	94t $0.26/kg		-Solution mined -dry mined, crush screen -upgrade through Sortex process, Thermoadhesive process or Recrystallization	50, 80 & 100 lb-s bulk-p	X	X	X	

s = Sacks
p = Pallet
pn = Pneumatic
b = Barrel
P = Potential

TABLE 5.1: INDUSTRIAL MINERALS DATA SHEET (continued)

MINERAL COMPONENT	QUANTITY USED (1) VALUE (2) (per well)	KEY SPEC. SOURCE	PROCESSING	PACKAGING & TRANSPORT	SOURCE			SUBSTITUTE
					ATLANTIC CANADA	CANADA	FOREIGN	
HEMATITE Fe_2O_3	815t $250/t	Platy Crystals S.G. 5.1 98.5 - 99.8% -200 mesh 92.0 - 96.0% -325 mesh 97.2 - 97.9% Fe_2O_3 Densimix Technical Data	-grind -flotation	100 lb-s	P?	P?	X	-Barite -Ilmenite -Galena -Siderite
CALCITE -Lime -Quicklime $CaCO_3$, CaO	Total Combined 30t -$0.07/kg -$0.47/kg -$0.47/kg		-crush, screen and classify. -lime, limestone in 6" lump form calcined in kiln produce pebble or lump CaO, $Ca(OH)_2$ hydrated	50 to 100 lb-s	X	X	X	
GILSONITE Natural Bitumens	6.5t $2.26/kg		-hydraulically mined -dry and screen				X	
MICA	3.0t $0.91/kg	Sized mica flakes Coarse, Medium, Fine	-crush, grind, -classify, using -screens, Humphrey spirals cyclones -flotation	50 lb or 25 kg-s		X	X	
SEPIOLITE	20t $0.48/kg	Viscometer Dial Reading at 600 rpm - 30 min Residue on wet screen U.S. sieve No. 200 - 8% max Moisture - 16% max API spec 13A	-crush -screen -grind -dry				X	-Bentonite -Attapulgite
GYPSUM $CaSO_4 \cdot 2H_2O$	325 kg $0.62/kg		-crush -grind -screen Calcining when making plaster of paris	50 to 100 lb-s	X	X	X	
SILICA SAND SiO_2	10t $0.11/kg		-wash, -classify		X	X	X	
GRAPHITE C	N/A		-crush -grind -classify				X	

s = Sacks
p = Pallet
pn = Pneumatic
b = Barrel
P = Potential

TABLE 5.1: INDUSTRIAL MINERALS DATA SHEET (continued)

MINERAL COMPONENT	QUANTITY USED (1) VALUE (2) (per well)	KEY SPEC. SOURCE	PROCESSING	PACKAGING & TRANSPORT	SOURCE			SUBSTITUTE
					ATLANTIC CANADA	CANADA	FOREIGN	
ASBESTOS $Mg_6(Si_4O_{10})(OH)_8$	N/A		-crush and dry -size by screens	50 to 100 lb-s	X	X	X	
DIATOMITE SiO_2 (Mostly powder form, some granular material)	N/A		-selective blend of crudes, simultaneous dry & mill using centrifugal blowers, removal of fine and coarse fraction by air separation		P	X	X	
POZZOLAN Volcanic Ash or Fly Ash	N/A		-crush and grind natural materials -collection of fly ash		P Fly Ash	P Fly Ash	X	
PERLITE Volcanic Glass	N/A		-heat to hydration -crush and size				X	
MINERAL WOOL Thick Silicate Fibers	N/A							
Witherite $BaCO_3$	N/A							
CORDIERITE $(Mg,Fe)_2\ Al_3\ (AlSi_5O_{18})$	N/A							
SMITHSONITE $ZnCO_3$	N/A							
ATTAPULGITE Clay	N/A	Viscometer Dial Reading at 600 RPM 30 min Residue on wet screen U.S. Sieve No. 200 8% max Moisture 16% max API SPEC 13A	-crush -screen -grind -dry	50 to 100 lb-s				-Bentonite -Sepiolite
MAGNESITE $MgCO_3$ (MgO)	N/A		Magnesite -crush grind -calcine or Produce from Dolomite -crush grind -calcine reaction with seawater		P? Dolomite			

s = Sacks
p = Pallet
pn = Pneumatic
b = Barrel
P = Potential

6.0 PERSPECTIVE ON THE MARKET FOR INDUSTRIAL MINERALS IN OFFSHORE EXPLORATION

6.1 The Size of the Industrial Minerals Market in Offshore Operations

This section provides a brief sketch of the relative and absolute significance of industrial minerals in offshore operations. Overall, the cost of mineral inputs appears to be around 2 percent of total drilling costs in the East Coast offshore. Although this figure understates the critical importance of mud, cement and their constituent materials, it does put the size of the market in perspective. Table 6.1 for example, shows mud and cement costs in Newfoundland and Nova Scotia in 1983. The total was around $47 million out of a total expenditure of $1.137 billion, of which something less than half would be industrial minerals.

The principal markets for industrial minerals in offshore operations are found in drilling muds and cements, which are likewise the focus of this report. In 1984, expenditures per day on total drilling operations ranged from $225,000 to $316,00 for Mobil, PetroCanada and Shell (N.S. Department of Mines and Energy). Of this, approximately half was accounted for by rig rental costs. Consumables accounted for 14 percent, the great majority of which was casing and fuel. Mud products accounted for 12 percent of the consumables and cement accounted for around 5 percent, making mud and cement 1.7 and 0.7 percent respectively of total cost per rig for the three companies.

These figures suggest substantially lower use of mud than those in Table 6.1 in which mud averages around 3.7 percent of total cost, and cement around 0.7 percent. The average for both mud and cement is slightly higher in Nova Scotia than in Newfoundland, a fact consistent with the generally greater well depths on the Scotian Shelf.

TABLE 6.1

VALUE OF MUD SYSTEM - ABSOLUTE AND PERCENTAGE OF WELL COST

	ACTUAL	------PROJECTED-----			
	1983	1984	1985	1986	AVERAGE
NOVA SCOTIA					
MUD $000	24576	26935	16140	2506	
MUD %	4.16	3.71	4.44	3.35	3.9
CEMENT $000	3359	5499	3526	482	
CEMENT %	0.56	0.76	0.97	0.64	0.73
NEWFOUNDLAND					
MUD $000	17531	14645	8569	8212	
MUD %	3.21	3.60	3.50	3.62	3.5
CEMENT $000	1834	2446	1784	1861	
CEMENT %	0.33	0.60	0.73	0.82	0.62
OVERALL					
MUD $000	42107	41580	24709	10718	
MUD %	3.7	3.7	4.1	3.5	3.7
CEMENT $000	5193	7945	5310	2343	
CEMENT %	0.45	0.70	0.80	0.80	0.70

Source: COGLA

Individual wells are highly variable. One sample of 14 wells for which complete mud costs are available, completed between late 1982 and mid-1985, averaged $813,000 for total mud materials, but the range was from $106,000 to $2,500,000. Depth is the most critical factor in the variation, but even costs per meter of hole varied from $45 to $486.

These figures are consistent with estimates by two industry informants, one of whom suggested that average mud costs would now be around $600,000/well and the other of whom said it would 'well under a million'. For cement, expert opinion ranges from $400,000 to $600,000 per well, which seems somewhat high in proportion to mud.

There has been a sharp downward movement over the past two years in the cost of the mud system and, apparently, also of cement. The same informants indicated that mud costs used to average $1.5 million per well, around double the current estimate. This figure is consistent with a comparison of proportions in a 1982 report by the Newfoundland Petroleum Directorate. The Newfoundland report (Table 6.2) estimated that mud and cement would account respectively for 7.3 percent and 1.9 percent of total costs. In both cases, the proportions are approximately double the estimates available in 1985.

There is also some evidence that the proportion of the mud cost generated by mineral products has declined slightly in recent years. Table 6.3 and Figure 6.1 both show the percentage of total mud cost accounted for by all minerals and barite in 14 wells. The data are too limited to support definite conclusions, but a slight downward trend can be observed. Regardless, the average is just over 40 percent, translating into a total cost per well of $340,000 for minerals used in mud. Recently, barite has accounted for around half of this cost. Cement, of course, is the major material cost in cementing operations. Taken together, industrial minerals appear to account for around 2 percent of total drilling costs.

TABLE 6.2

PROJECTED MUD AND CEMENT COSTS
NEWFOUNDLAND OFFSHORE
1981-1990

	HIGH	MEDIUM	LOW	AVERAGE
MUD/WELL				
- $ million	1.37	1.23	1.05	
- %	7.2	7.36	7.49	7.3
CEMENT/WELL				
- $ million	0.37	0.33	0.28	
- %	1.9	1.98	2.02	1.9

Source: Newfoundland Petroleum Directorate
'Direct Economic Impact of Total Drilling Activity, 1981-1990', September, 1982.

TABLE 6.3

PROPORTION OF MUD COST ACCOUNTED FOR BY INDUSTRIAL MINERALS, SELECTED WELLS 1980 TO 1984

		% OF VALUE MINERALS	% OF VALUE BARITE
WELL NUMBER			
(earliest-1980)	1	53.8	35.7
	2	55.1	34.6
	3	64.2	29.6
	4	46.5	16.0
	5	62.5	46.1
	6	40.1	5.3
	7	26.9	20.9
	8	37.1	9.0
	9	46.5	12.2
	10	36.6	8.4
	11	36.2	10.8 (+12.7% hematite)
	12	49.0	20.4
	13	8.8	1.9
(latest-1984)	14	33.9	29.5
AVERAGE		42.6	20.0

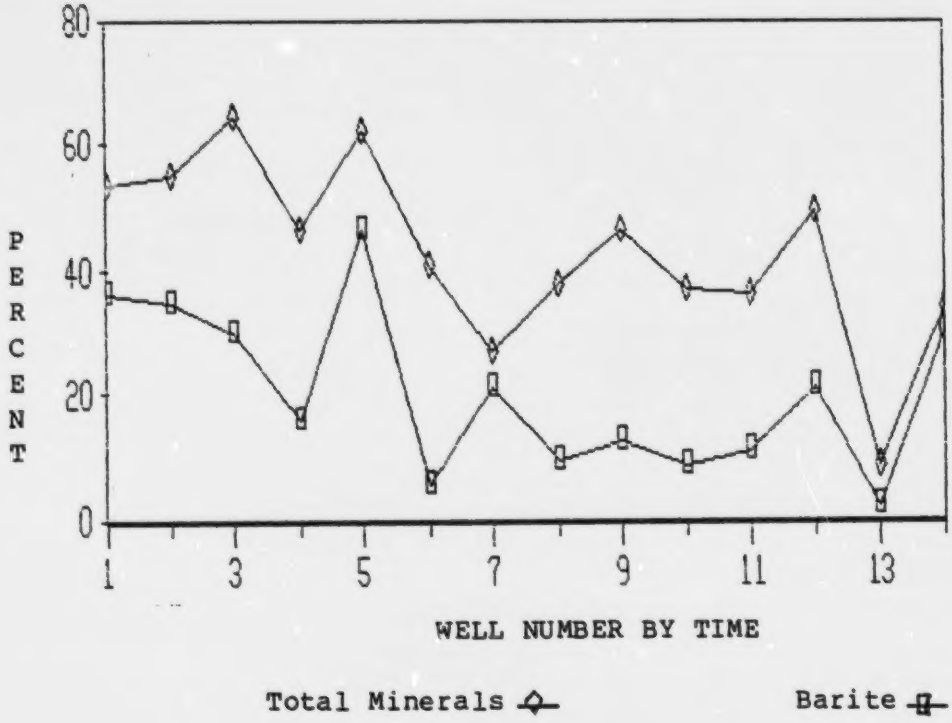


FIGURE 6.1

PROPORTION OF MUD COST ACCOUNTED FOR BY MINERALS

6.2 World-Wide Usage of Industrial Minerals in Mud

Table 6.4 outlines industrial minerals usage in drilling in three different areas: the United States in 1982, the North Sea in 1976 and the Canadian East Coast offshore in 1983 and 1985. Although the data are incomplete, and in some cases only estimates, they provide some indication of what might be described as the range of industry standards.

The most striking observation is the enormous variability among the three sets of data, explained in part by the lack of consistent data sets, in part by time, and in part by location. Barite fairly consistently represents just over half of the total mineral weight in the Canadian offshore and U.S. cases. The very high proportion of barite in the North Sea is misleading, since the absolute weight of barite per well is consistent in order of magnitude with the Canadian figures. The reason barite appears so high proportionately is that a relatively minimal amount of bentonite appears in the North Sea figures.

With the exception of barite, the variation in all minerals prevents generalization. Only the U.S. shows perlite and diatomaceous earth, gypsum and salt. But the U.S. figures show no caustic soda which is reported everywhere else. Lignite is highly variable, showing up in very high proportions in the 1983 Canadian estimate. We shall see that, while some of these differences are due to the different approaches to estimating and reporting, others are due to the variance in practice over time and from place to place. This is a function of technological change, well depths and conditions, differences between onshore and offshore situations, and the relative distance from sources of supply. It will be clear that there is a significant variation even in an area as constricted as the Canadian East Coast offshore.

TABLE 6.4

COMPARATIVE MINERALS USAGE IN MUD
U.S., NORTH SEA, CANADA OFFSHORE

MINERAL	U.S. 1972 TOTAL USE (tons)	NORTH SEA 1976 PER WELL (kg)	CANADIAN EAST COAST 1983 PER WELL (kg)	TYPICAL EAST COAST WELL 1985 (kg)
BARITE	880,000	544,000	360,000	1,200,000
% OF TOTAL	57.9	96.2	51.7	67.8
BENTONITE	400,000	10,000	272,000	500,000
% OF TOTAL	26.3	1.7	39.1	29.1
ATTAPULGITE/ SEPIOLITE	60,000	---	---	---
% OF TOTAL	3.9	---	---	---
LIGNITE	12,000	---	20-55,000 (avg 37,500)	34,000
% OF TOTAL	0.6	---	5.4	1.9
PERLITE/ DIATOMACEOUS EARTH	50,000	---	---	---
% OF TOTAL	3.2	---	---	---
GYPSUM	31,000	---	---	---
% OF TOTAL	2.0	---	---	---
SALT	75,000	---	---	---
% OF TOTAL	4.9	---	---	---
SODA ASH	10,000	3,000	10-20,000 (avg. 15,000)	6,200
% OF TOTAL	0.6	0.5	2.1	0.4
LIME	0.0	600	0.0	5,400
% OF TOTAL		.01		0.3
CAUSTIC SODA	---	8,000	2-14,000 (avg. 8,000)	25,000
% OF TOTAL	---	1.4	1.1	1.4
BICARBONATE OF SODA	---	---	3-5,000 (avg. 4,000)	---
% OF TOTAL	---	---	.05	---

Sources: U.S. figures - 'Industrial Minerals', September 1972
North Sea - 'Industrial Minerals', September, 1976
Canada - 1983 Canadian Supply Gap Study
1985 Magcobar Estimate

7.0 RECENT INDUSTRIAL MINERALS USE IN ATLANTIC CANADA

In order to determine actual usage in the Canadian East Coast offshore, we have assembled a sample of wells for which detailed information was available on mud and cement use. The consistency of the data was uneven due to different reporting practices and the number of recent wells for which data have not been reported, although the cooperation of the mud companies helped alleviate this latter difficulty.

Our data base consists of 28 wells for cement and 29 wells for mud, extracted from a sample frame consisting of all wells spudded in the East Coast offshore from 1980 to date. The cut-off point is wells which reached Total Depth (TD) by July 1985. The sample frame consists of 82 wells and the cement sample is therefore 34 percent and the drilling fluid sample 35 percent.

The principal variables affecting the use of drilling fluids and cement are depth, formation conditions and experience. Particular formation conditions are associated with different areas. For example, compared to the Grand Banks, the Scotian Shelf is characterised by fractured and geo-pressured formations, and considerably deeper holes. Offsetting this, however, is the much deeper water on the Grand Banks and off Labrador which requires correspondingly longer marine risers to reach the seafloor and thus larger quantities of mud.

Average Spud Depth
Wells Spudded 1980 and Later

	Grand Banks	Scotian Shelf	Labrador	Gulf of St. Lawrence
No. of Wells	33	34	11	4
Average TD	4326m	5084m	3224m	2629m

The significance of the different variables is very difficult to specify but it is considerable. For example:

> Depth obviously influences the total quantity of materials used in a hole. In the case of barite, the relationship is affected by the increasing formation pressure and the weight of the fluid in the hole. The quantity of the fluid phase (oil, water, seawater) is also a direct function of depth, but other materials, although they often increase with depth, do not do so in a consistent fashion. Depth affects cement mainly in regard to the use of setting retarders or accelerators.
>
> Formation conditions is the critical variable but there is little that can be done to quantify the difference. Geopressured zones will require more weighting materials such as barite or hematite, high temperatures may require sepiolite in substitute for bentonite or chrome lignite as a thermal stabilizer and reactive shales may require large quantities of shale control inhibitors such as potash. Cement is similarly affected by hole conditions. High formation pressure may require hematite as a weighting agent and high temperatures may require silica sand as a reagent to prevent brittlenesss.
>
> Finally, experience has a significant effect. Experience with a formation may gradually allow high pressure zones to be approached with later mud weighting and less weighting thereby saving barite. Faster drilling through reactive shales may eliminate the need for shale control inhibitors such as potash.

We have taken these considerations into account in assessing the adequacy of the sample. Tables 7.1 and 7.2 show the extent of the cement and drilling fluid samples. For cements, we have sampled 28 wells predominantly from the Grand Banks. The sampling for drilling fluids is much more evenly distributed.

TABLE 7.1

CEMENT - WELLS SURVEYED

COMPANY	GRAND BANKS	SCOTIAN SHELF	LABRADOR (Gulf of St. Lawrence)
MOBIL	Bonanza M-71 Sheridan J-87 Rankin M-36 Nautilus C-92 Hibernia K-14 Hibernia C-96 Hibernia B-27 Linnet E-63 Hibernia K-18 Hebron I-13 S.Tempest G-88 Hibernia B-08 Ben Nevis I-45 Hibernia O-35 Hibernia G-55		
PETROCANADA		W.Esperanto B-78 N.Banquereau I-13	CorteReal P-85 Rut H-11 Roberval C-02 Ogmund E-72 N.Leif I-05 N.Bjarni F-06
HUDSON'S BAY OIL AND GAS			Beaton Pt. F-70 East Pt. E-47
CHEVRON			S.Labrador N-79
CANTERRA			Ralegh N-18
SHELL		Shubenacadie H-100	
TOTAL	15	3	10

TABLE 7.2

DRILLING FLUIDS - WELLS SURVEYED

COMPANY	GRAND BANKS	SCOTIAN SHELF	LABRADOR (Gulf of St. Lawrence)
MOBIL	Ben Nevis I-45 Bonanza M-71 Hebron I-13 Hibernia B-08 Hibernia K-18 Hibernia O-35 Hibernia G-55 Linnet E-63 S.Tempest G-88	Olympia A-12 Venture B-13 Venture B-43 W.Venture N-91	
PETROCANADA	TerraNova K-18 TerraNova K-08	Bonnet P-23	StPaul P-91 CorteReal P-85 Pothurst P-19 Rut H-11
SHELL		Alma F-67 Glenelg H-38 Glenelg J-48 Glenelg E-58A Peskowesk A-99 Shubenacadie H-100	
CANTERRA	PortauPort J-97		Hopedale L-39
HUSKY/BOW VALLEY		Evangeline H-98	
TOTAL	12	12	5

As Table 7.3 shows, the sample distribution for muds is precisely the same as the distribution of wells in total. Figure 7.1 shows the depth distribution profiles of the total sample frame and the two samples. Table 7.4 shows the median and mean depths. From these exhibits, it can be safely concluded that the samples are representative of East Coast offshore conditions in the past five years. Generally, we are confident that the different conditions on the Scotian Shelf and Grand Banks are well covered in the mud sample. Some caution may be indicated in the cement sample since the conditions in the large number of Grand Banks wells may lead to lower use of commodities whose use is greatly affected by temperature, pressure or depth. However, the amounts used are very small so that the nature of the total market is not unduly distorted.

Table 7.5 and 7.6 show the complete results for both mud and cement. Total use is shown together with the number of wells in which the mineral was used, and the average use based only on those wells in which the mineral was used. This provides a representative picture of the use of industrial minerals in the past four years in the Canadian East Coast offshore. Where there are marked differences from the estimates in Table 6.4, it is because our sample is more accurate and specific to local conditions.

The total use per well in Tables 7.5 and 7.6 can be summed to arrive at the total minerals used, but the average per well should not be summed. No single well uses all the materials listed, and only barite, bentonite, bicarbonate of soda, soda ash, calcium chloride, caustic soda, lime, and cement are listed in over half of the wells. Moreover, while the data present a fair historical picture, they should not be extrapolated into the future without reference to possible changing conditions. The next section, among other things, tries to indicate possible directions for use of different minerals.

TABLE 7.3

GEOGRAPHIC DISTRIBUTION SAMPLE FRAME AND SAMPLES

	SAMPLE FRAME		CEMENT SAMPLE		MUD SAMPLE	
	#	%	#	%	#	%
GRAND BANKS	33	41	15	53	12	41
LABRADOR	11	13	8	28	4	14
GULF	4	5	2	7	1	4
SCOTIAN SHELF	34	41	3	11	12	41
TOTAL	82		28		29	

TABLE 7.4

MEAN AND MEDIAN DEPTHS

	SAMPLE FRAME	DRILLING FLUID SAMPLE	CEMENT SAMPLE
TOTAL WELLS	82	29	28
MEAN DEPTH	4394M	4509M	4388M
MEDIAN DEPTH	4500M	4520M	4462M

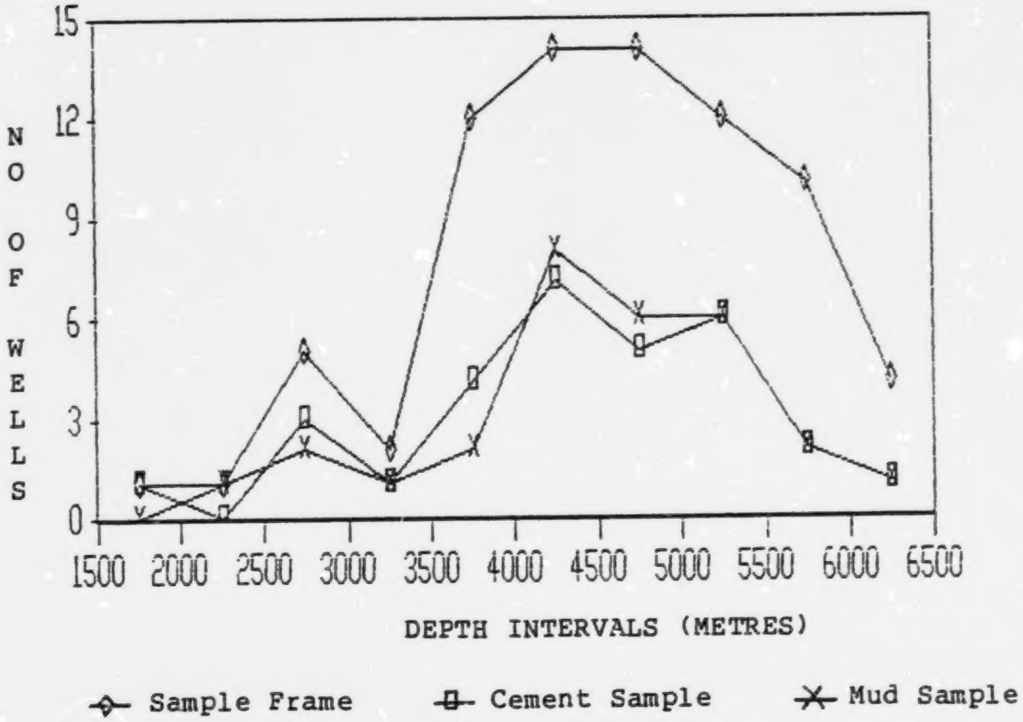


FIGURE 7.1

WELL DEPTH PROFILES

TABLE 7.5
MINERALS USE IN MUD - 29 WELL SAMPLE

MINERAL	TOTAL USE (kg)	PERCENT OF TOTAL	USED IN # WELLS	AVERAGE PER WELL(kg)
BARITE	30,966,000	71.29	28*	1,105,929
BENTONITE	6,493,503	14.95	28*	231,910
CALCIUM CARBONATE	15,520	0.03	4	3,880
CALCIUM CHLORIDE	248,110	0.57	15	16,054
CAUSTIC SODA	464,100	1.06	28	16,575
CHROME LIGNITE	581,180	1.34	13	44,706
GILSONITE	26,050	0.06	4	6,512
GYPSUM	1,625	Negligible	5	325
HEMATITE	815,000	1.87	1	815,000
LIGNITE	474,705	1.09	5	94,941
LIME	39,037	0.08	24	1,627
MICA	37,150	0.08	11	3,377
POTASH	2,084,375	4.79	12	173,698
QUICK LIME	124,850	0.28	5	24,970
SALT	850,680	1.95	9	94,520
SEPIOLITE	40,114	0.09	2	20,057
SODA ASH	92,040	0.21	24	3,835
SODIUM CARBONATE	76,818	0.17	21	3,658
TOTAL	43,430,857			

* One well report did not show barite and bentonite because obtained by separate contract. This does not mean that none wa used.

TABLE 7.6
MINERALS USED IN CEMENT-28 WELL SAMPLE

MINERAL	TOTAL USE (kg)	PERCENT OF TOTAL	USED IN # OF WELLS	AVERAGE PER WELL (kg)
CALCIUM CHLORIDE	56,768	0.54	26	2,183
API CLASS G CEMENT	10,362,000	99.11	28	370,071
HEMATITE	2,420	0.02	1	2,420
ILMENITE	2,412	0.02	1	2,412
SILICA SAND	31,535	0.30	3	10,511
TOTAL	10,455,135			

8.0 MINERALS USED IN OFFSHORE EXPLORATION: MARKET CONDITIONS

8.1 Barite

Barite is the most familiar mineral used in drilling fluids, and by weight and value the most important. Of total weight of minerals used in our 29 well sample, barite accounted for just over 71 percent. The reasons for use of barite are straightforward: it is a relatively effective weighting agent (S.G. 4.2-4.5); it is inert, and therefore has no effect on the chemical properties of the mud or the formation; and it is easily ground and non-abrasive. Finally, it is virtually ubiquitous, making it readily available for drilling operations anywhere in the world, and it is relatively cheap compared to such substitutes as galena, hematite and ilmenite.

Total barite used in the mud sample was just over 31,000 tonnes, or 1100 tonnes per well. This figure is consistent with the information given by the experts interviewed, including an estimate from Magcobar of 1200 tonnes per well. This suggests that the total barite used in the 82 wells drilled off Atlantic Canada from 1980 to mid-1985 would have been around 90,000 tonnes or 20,000 tonnes per year on average.

Use varies from as little as 41 tonnes per well to as high as 3,553. Although one source suggested that there was a more or less linear relationship between depth and barite use (see Figure 4.1), our data suggest a relationship which is more geometrical, and discontinuous between 4500 and 5000 meters (see Figure 8.1). Holes under 4,500 meters, with one exception, show use at less than 0.2 tonnes per meter and average around 0.1 tonnes per meter. Holes over 4500 meters use from .05 to .65 tonnes per meter but average slightly over 0.3 tonnes. This observation has considerable relevance for projecting future use. Were drilling activity to shift to the Grand Banks, where the average depth is under 4500 meters, barite use would be expected to decline

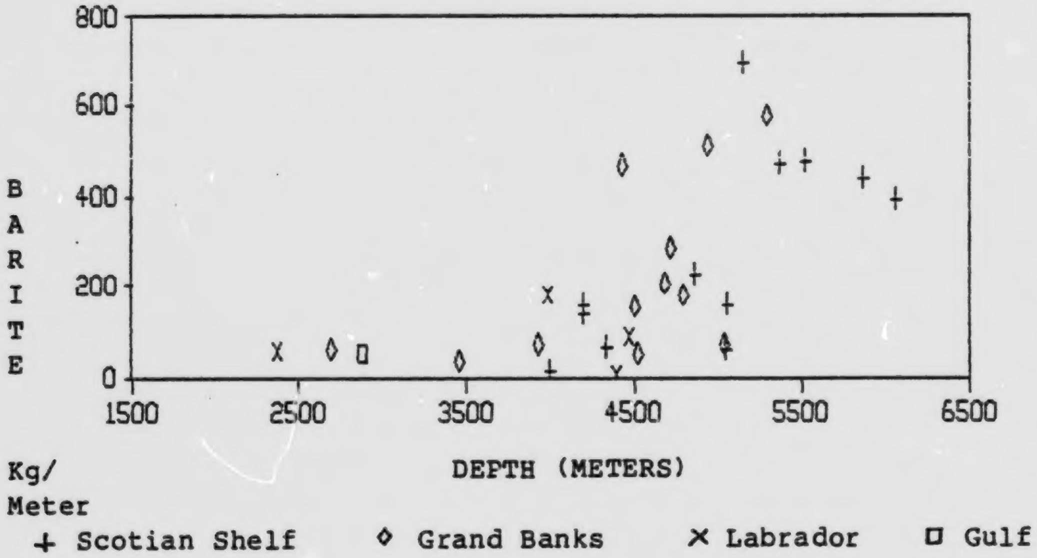


FIGURE 8.1
BARITE USE AND WELL DEPTH

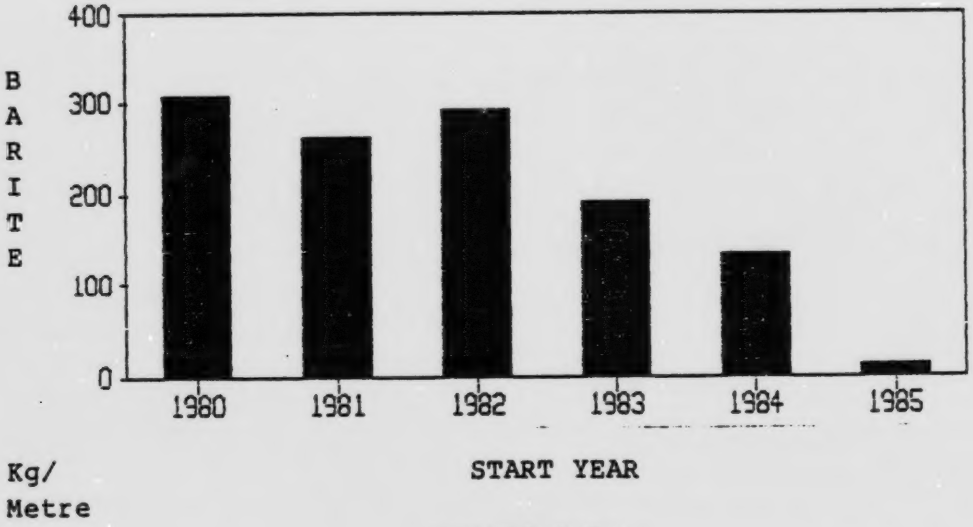


FIGURE 8.2
BARITE USE OVER TIME

and more particularly, to decline somewhat disproportionately to the decline in total well depth. Table 8.1 outlines the differences in the sample.

Two other factors could also tend to depress barite use. One is the effect of increasing experience. As a drilling area becomes known to the drilling operators and the high pressure zones can be better anticipated, it is possible to weight-up the mud later and to a lesser degree while still maintaining necessary safety margins. One informant suggested that, partly for this reason, barite use in the East Coast offshore has declined by around 50 percent in the past few years. Although our data are too narrow to reliably confirm such a trend, Figure 8.2 shows use per meter over time. It tends to suggest that there has been a general decline in barite use.

The second important factor which could depress barite use in the future would be increased use of substitute weighting agents, notably hematite and ilmenite. Later sections describe the reasons why increased use of these two minerals seems possible.

Barite prices have been extremely volatile in recent years. In 1981, the sales price (price received by the mud company)* jumped from $220 to $450 per tonne, but by mid-1985 it had dropped back to a range of $170 to $225. The reasons for the price volatility seem clear: barite use rises and falls with drilling activity, which accounts for some 80 percent of the total barite market. Oil drilling activity is, in turn, driven by oil price. Figure 8.3 shows the relationship between oil price, drilling activity in the U.S., and barite use in U.S. drilling from 1971 to 1984, and barite price in Atlantic Canada from 1980 to 1984.

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* Throughout this report, 'sales price' refers to price paid by the operator to the mud company. 'Cost price' refers to the price paid by the mud company to the mineral supplier.

TABLE 8.1

BARITE USE AND WELL DEPTH
GRAND BANKS, SCOTIAN SHELF, LABRADOR AND GULF
28 WELL SAMPLE

AREA	PERCENT OF WELLS IN SAMPLE	TOTAL METERS OF HOLE DRILLED	PERCENT OF TOTAL METERS DRILLED
GRAND BANKS	43	52,991	42.0
SCOTIAN SHELF	43	59,668	47.2
LABRADOR AND GULF	14	13,714	10.8

AREA	TOTAL BARITE USE (TONNES)	PERCENT OF BARITE USED
GRAND BANKS	12,427	40.1
SCOTIAN SHELF	17,288	55.8
LABRADOR AND GULF	1,251	4.0

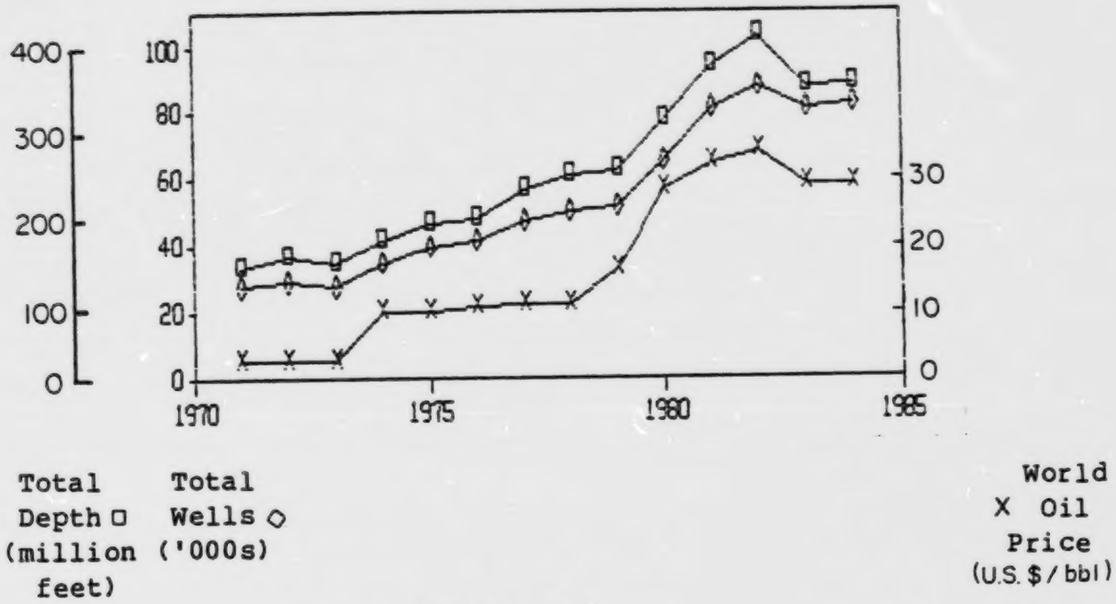


FIGURE 8.3
RELATIONSHIP BETWEEN WORLD OIL PRICE,
DRILLING ACTIVITY, BARITE USE AND BARITE PRICE

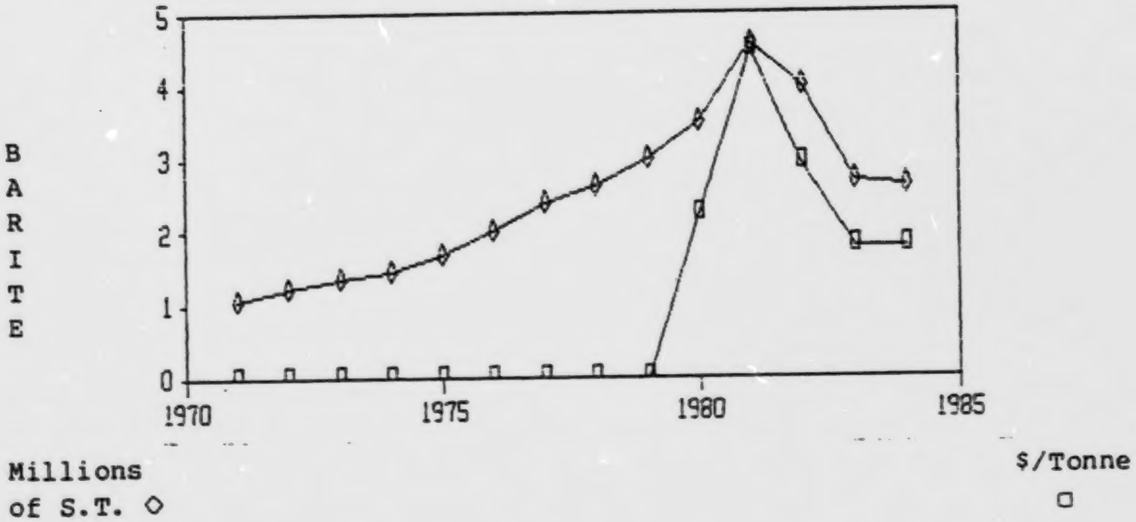


FIGURE 8.4
BARITE USE IN THE UNITED STATES COMPARED TO
PRICES QUOTED IN CANADA

The first OPEC price hike in 1973 led to a steady increase in the number of wells drilled and the total depth of wells drilled in the United States. The second big price hike in 1978-79 led to a further and dramatic increase in wells drilled and total depth drilled as exploration moved to less traditional areas and deeper zones. As oil prices fell after 1982, drilling activity fell with it. Barite use in the U.S. and barite prices in Atlantic Canada tracked these events very closely as Figure 8.4 shows. In brief, it appears that the world oil price is a good indicator of barite prices.

Another factor which will tend to depress barite prices is the emergence of Third World producers. In 1976, developed nation producers accounted for 45.7 percent of world production, with the United States alone accounting for 20.7 percent (see Figure 8.5). At the price and production peak in 1981, the United States had increased its share to 31.5 percent and developed nation producers in total had held their share steady. However, at the same time, Third World producers were rapidly expanding, and their share of the market grew from 37.1 percent in 1976 to 43.1 percent in 1981. In the last two years, concurrent with falling barite prices and production, the United States' share of the market has dropped by two-thirds and the developed nations now account in total for only 31.4 percent. Third World producers, probably in a better position to respond to the falling prices because of lower production costs, have captured 52.6 percent of the total market.

For both demand and supply reasons, barite prices are likely to remain depressed in the foreseeable future. On the demand side, world oil prices are generally expected to continue their decline (perhaps even dramatically) for the next few years, although they could stabilize and move upwards in the 1990s. On the supply side, the substantial expansion in barite production capacity in response to the 1981 boom means that even a significant increase in demand could be handled by current over-capacity. Additionally, the market is now dominated by low-cost producers and the overall effect is that heavy price competition would probably be maintained even if demand were to unexpectedly rise.

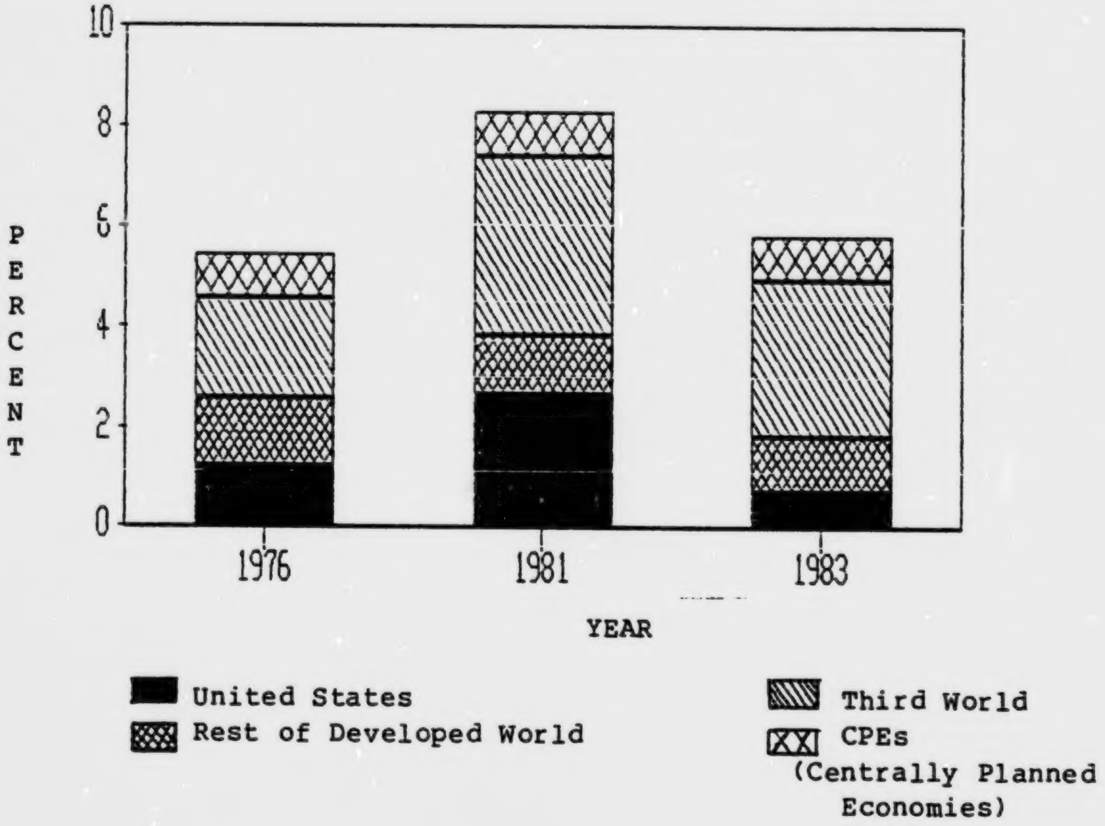


FIGURE 8.5

WORLD BARITE PRODUCERS
MARKET SHARES: 1976, 1981, 1983

Sources of barite for drilling in the East Coast offshore vary widely in response to availability, price and encouragement to purchase locally.

Magcobar, for example, reports using barite from Walton (mine waste piles), Bass River, and Ireland (which is reported as the most economical source). In Newfoundland, they use Colliers Point barite.

National Mud used to purchase barite in Western Canada and from offshore (especially Morocco) but more recent purchases have been from Nova Scotia (Novex and Brookfield) and they have invested in Scottsville to have first claim on supply.

Baroid originally purchased predominantly from outside Canada and largely from NL's base in New Orleans. Buchans was the main supplier from 1981 to 1984, but price drops since then have forced them to foreign suppliers and, in particular, to China.

Technifluids' experience is similar to Baroid's in that, up to 1984, they relied solely on an Atlantic Canadian supplier (Novex). Since then, however, price pressure has forced them back to foreign sources although they have maintained discussions with suppliers such as Scottsville Mineral Resources and Colliers Point.

Although the total cost of the mud system is only a small fraction of total drilling cost, price has been the main competitive element in the past few years. As times have gotten leaner, mud companies wanting to get on board a rig have had to shave margins ever more closely. According to one informant, margins are now just over 20 percent compared to 40 to 50 percent in the early 1980s. Since barite accounts for 30 to 50 percent of the total product sales, it must be sourced competitively.

Given the state of world barite markets, it is hardly surprising that domestic producers have been in tight circumstances since 1984. The data below illustrate some representative 1985 costs as quoted by informants.

Sales Prices for Barite in 1985:
6 quotes of $169 - $225 per tonne
Average of $187 per tonne

Cost prices of barite per tonne from various sources:
(Finished product, landed dockside, Halifax or St. John's)

- Nova Scotia supplier #1	$165
- Nova Scotia supplier #2	$150
- Newfoundland supplier	$135
- Foreign source (unspecified)	$ 80
- China	$ 60
- Morocco (crude)	$40 - 65

While these data are anecdotal, they are consistent with U.S. data which also show a roughly two to one differential between domestic and imported barite (landed Gulf of Mexico, April 1985). The reasons why domestic sources in Canada are twice as expensive as imported are not easy to pin down with precision, but production costs appear to be the main problem. For the Nova Scotia and Newfoundland sources quoted at $150 and $135, basic product cost appears to be around $90 to $100, or triple the product cost indicated for a Chinese source. The reasons for such relatively high costs include, depending upon the actual source, the nature of the deposit, insufficient production runs to use capital efficiently, high labour costs and high electricity costs. Additionally, domestic producers pay a transportation premium. Road transport from Buchans to St. John's, for example, reportedly costs $40 per tonne compared to $25 per tonne for seaborne shipping from China.

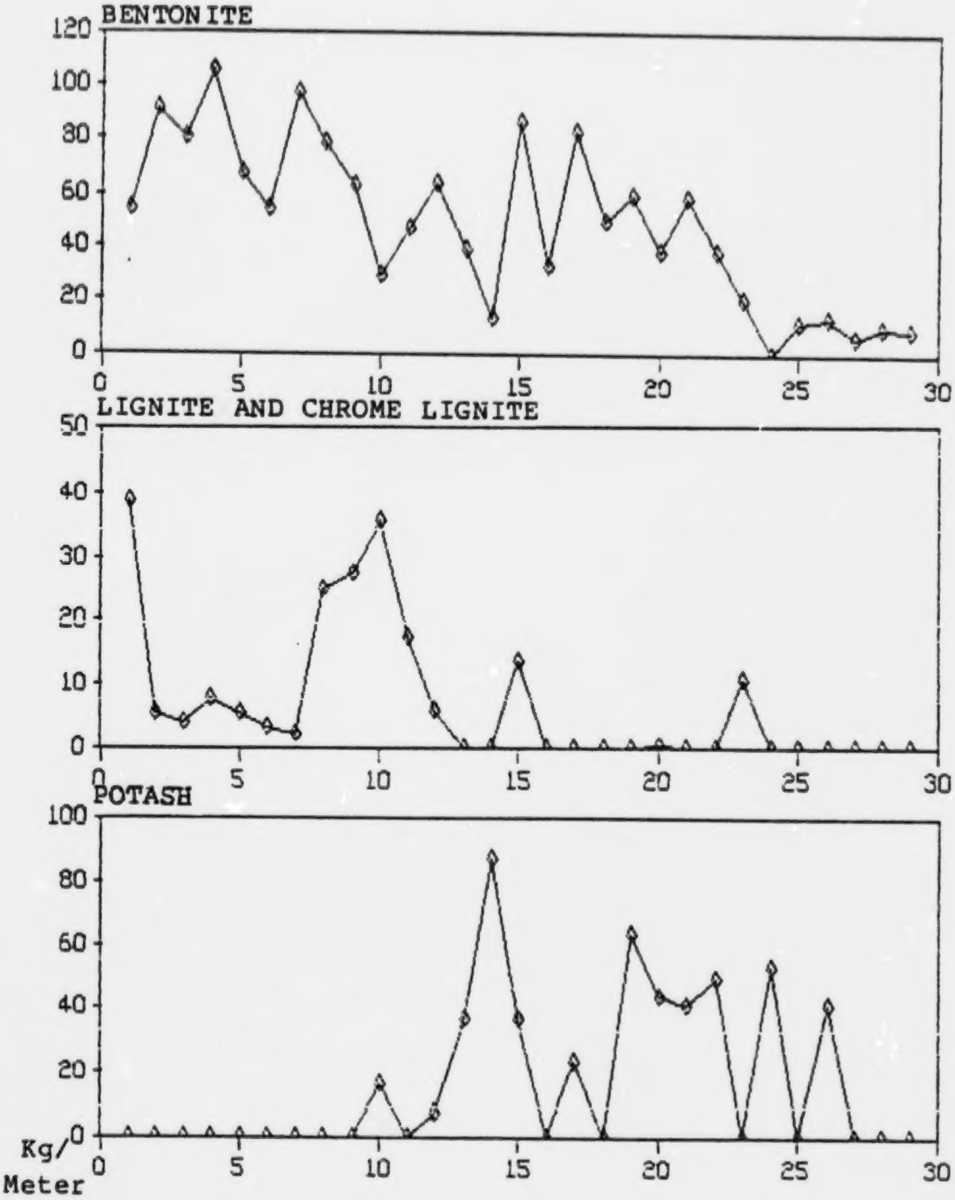
To sum up, price is a key consideration to the mud companies. In order to maintain a 40 percent margin on barite selling for $170-$200 per tonne, the cost of the finished product delivered dockside would need to be in the $120 to $140 range. Looking at it another way, one informant indicated that local supply would warrant a 20 percent premium as the cost of meeting local content requirements. Set against current import prices, this suggests that local suppliers would have to be able to deliver finished product dockside for $100 per tonne at the outside if they are to be competitive with Third World suppliers.

8.2 Bentonite

Bentonite is the second most common mineral used in drilling mud, accounting for almost 15 percent of total weight of materials in the sample, or 6493 tonnes (around 232 tonnes per well). The weight of bentonite used amounts to about 21 percent of the weight of barite, a sharp contrast to United States experience where the equivalent figure is closer to 43 percent. It is in some contrast to the 1983 supply gap study (see Table 5.4) which suggested 270 tonnes of bentonite per well. This last point is important since it shows what has happened to bentonite use in the East Coast offshore in recent years.

Bentonite performs two distinct functions in drill mud: it makes the mud viscous so as to increase its capacity to suspend and remove drill cuttings, and it forms a filter cake on the side of the hole to prevent fluid loss to the formation. Despite having both these qualities, bentonite has a number of disadvantages. Chief among them are its incompatibility with salt water and the fact that it increases the solids content of the mud. These two disadvantages are particularly relevant in the East Coast offshore where fresh water for mixing bentonite is at a premium and where deep holes require more barite, hence fewer other solids.

In East Coast offshore and North Sea practice, organic polymers are often substituted for bentonite, particularly in the lower parts of holes and in production zones. Polymers are low bulk, easy to handle and have less solids content. Although they do not have the same filtration qualities as bentonite, their other advantages offset this. As Figure 8.6 and Table 8.2 show, there has been an uneven but substantial decline in bentonite use in the East Coast offshore in the past five years. The six wells drilled in 1980 averaged just over 4600 meters and used over 75 kilograms of bentonite per meter. In contrast, the seven 1984 wells averaged about the same depth but used only 19.0 kilograms of bentonite per meter.



WELL NUMBER BY DATE

FIGURE 8.6
USE OF BENTONITE, LIGNITE AND CHROME LIGNITE,
AND POTASH OVER TIME

TABLE 8.2

USE OF BENTONITE, POTASH, AND LIGNITE AND CHROME LIGNITE
29 WELL SAMPLE - BY DATE

WELL	DATE MO/YR	DEPTH (METERS)	BENTONITE KG/M	POTASH KG/M	LIGNITE AND CHROME LIGNITE KG/M
O-35	1/80	4788	54.2	0	38.8
I-45	1/80	4932	90.6	0	5.3
B-08	3/80	4435	79.9	0	4.0
B-13	8/80	5368	105.3	0	7.5
G-88	9/80	4674	66.8	0	5.0
G-55	10/80	3460	54.0	0	2.8
I-13	1/81	4723	97.8	0	1.8
K-18	2/81	5039	79.6	0	24.6
B-43	6/81	5872	62.2	0	27.2
A-12	3/82	6064	28.9	16.0	35.4
M-71	5/82	5295	46.8	0	17.2
E-63	7/82	4520	63.6	6.5	5.7
H-100	11/82	4200	39.0	35.7	0
K-08	2/83	4500	12.1	86.4	0
J-48	2/83	5148	87.2	36.1	13.3
L-39	7/83	2369	31.8	0	0
H-11	8/83	4473	83.2	23.5	0
P-19	8/83	3992	50.1	0	0
P-91	9/83	2885	59.9	63.0	0
F-67	12/83	5054	37.2	42.6	0
P-23	1/84	4336	57.9	40.3	0
H-98	3/84	5054	37.8	49.6	0
C-62	5/84	5520	19.9	0	10.8
J-97	6/84	2700	0	53.4	0
E-58A	7/84	4192	11.6	0	0
K-18	7/84	5039	9.9	31.6	0
P-85	8/84	4395	6.1	0	0
H-38	10/84	4867	9.3	0	0
A-99	4/85	4003	7.7	0	0

The reasons for this shift, as mentioned, are the difficulties with handling bentonite offshore (and the advantages of polymers in such situations), the need to reduce solids content in deep wells and the increasing use of KCl muds. The other big factor is the approximate price parity between bentonite and polymers created by transportation costs.

Typically, the major disadvantage to polymers is their cost, estimated by one informant to be about three times as much as bentonite in Gulf of Mexico operations. In Nova Scotia and even more so in Newfoundland, the cost of transport and handling eliminates this difference. One informant constructed it as follows:

Location	Product Cost*	Transport	Total	+Margin	Sales Price
Gulf	\$2.50-\$3.00	0	\$2.50-\$3.00	66-100%	\$ 5.00
East Coast	\$2.50-\$3.00	\$4.00-\$4.50	\$6.50-\$7.50	66-100%	\$13.00

* 100 lb. sack

In fact, actual sales prices (sample of 14) between 1983 and 1985 have averaged closer to \$14.00, although 1985 prices are around \$12.70. In short, even in Nova Scotia, the differential is virtually eliminated. In Newfoundland, where one informant estimated transport costs for bentonite to be closer to \$8 per 100 lb. sack, the cost advantage would actually rest with polymers.

Finally, it should be noted that any shift to oil based mud will eliminate bentonite use completely. Instead, an organophilic clay would be used as a filtration agent and a viscosifier in quantities of 5 to 10 percent of the bentonite now used.

All bentonite is purchased from Wyoming which is the highest quality source available. Although some bentonite is mined in Western Canada, it is shipped to Wyoming for blending to bring it up to A.P.I. specifications.

8.3 Potash (Sylvite)

Potash is the third most commonly used mineral, at 2084 tonnes, although its use is restricted to 12 wells in the sample of 29. Thus, when it is used, the quantities per well (173 tonnes average in this case) are in the same order of magnitude as bentonite. Indeed, potash use tends to be inversely proportional to bentonite use since bentonite does not work with KCl muds and polymers are used in its place. This shows to some degree in Figure 8.6.

Potash acts as an inhibitor of reactive shales. By preventing water loss to the formation, it keeps such shales from swelling and sloughing into the hole. Different informants had different views about future potash use. One felt that experience gained would allow faster penetration of shale formations and hence less need for potash. Another felt that potash use is on the increase (which our data would tend to support). It is clear that to the extent that oil base muds are used, potash will not be used at all.

The main source of potash for all companies is Saskatchewan, an interesting fact given the price differential for shipping from Saskatchewan as opposed to Sussex, New Brunswick. Prices quoted for potash in February 1984 f.o.b. Saskatchewan ranged from $55.00 to $61.50 per short ton. Bagged product is $26.00 more, or $81.00 to $87.00 per ton. Since all mud companies use bagged product, this is the relevant number. The cost of shipping triples the total cost and makes the Sussex product (assuming comparable product cost) by far the cheaper. The difference is shown below:

	Cost of Product Bagged per S.T.	Shipping	Total
Saskatchewan	$85.00 (approx.)	$150 (approx.)	$235
New Brunswick	assume same	$40 (approx.)	$125

Recent sales prices of potash ranged from 37 cents to 62 cents per kilogram between September 1983 and November 1984, averaging around 48 cents, or around $440 per short ton. Although gross margins on potash are obviously fairly healthy, even at a cost of $235 per short ton, the incentive for using Sussex potash would seem to be fairly strong.

The reasons for not buying the New Brunswick product vary somewhat from informant to informant. All agreed that the Sussex product has a purity problem, due to an amine detergent used in processing which is left on the product and which causes foaming of the mud. Where the informants differed was in the absolute and relative importance of this problem.

One informant felt that the cost of defoamers and the risk of completely ruining the mud system were sufficiently great to offset the price advantage. Experience in the West with a similar product has led to mud systems being dumped, which is less serious there because of much shorter wells and greater accessibility. Tests on the Sussex product have indicated similar behaviour and his company has accordingly decided not to use it.

Another informant agreed that it was a problem, but that they had used Sussex potash and had solved the problem using an oil base defoamer (aluminum stearate and diesel). Price was the key consideration in his view and the Saskatchewan product was available in Newfoundland at a lower price than the New Brunswick product. This suggests that either the price of Sussex potash is seriously out of line (which seems improbable for a standard commodity in world trading) or that costs of shipping to Newfoundland are much higher than to Nova Scotia.

Finally, a third informant indicated that the foaming problem was not serious. However, he understood from contacting the Sussex operation that all their product was committed to overseas markets and would not be available in any event.

8.4 Chrome Lignite and Lignite

Together, chrome lignite and lignite comprise 1055 tonnes of material in our sample, fourth after potash in total quantity. They are found in appreciable quantities in 14 wells for an average of 75 tonnes per well.

Lignite has a variety of uses; among them, as a thinner for water muds, filtrate reducer, oil emulsifier and stabilizer for muds in high temperature conditions. Chrome lignite has particularly good filtration and thermal stability properties. Because it is slightly acidic, lignite is often causticized and its use, therefore, is often associated with the use of caustic soda. Lignite also tends to be used in association with bentonite where, as a thinner, it helps to reduce the gel strength. In our sample, there is an apparent relationship between the use of lignite and chrome lignite and the use of bentonite, which is to say, the 14 wells showing lignite or chrome lignite account for over 70 percent of all bentonite observed. Indeed, the use of both lignite and chrome lignite has declined dramatically in the past two years, along with the use of bentonite. Of the total lignite and chrome lignite in our sample, almost 88 percent shows up before 1983. In the two and a half years since then, only two wells show any chrome lignite at all. The use of lignite and especially of chrome lignite is also associated with depth where its capacity to impart thermal stability becomes important. There is no noticeable decline in average well depth over time in our sample, however, so this would not explain declining lignite use. While lignite is primarily used in water-base muds, lignite derivatives are used to a limited extent in oil-base muds.

Sales prices for lignite appear to be in the order of $0.47 per kilogram (1984). Chrome lignite sells for more than double, at prices ranging from $1.01 to $1.32 per kilogram in 1983 and 1984.

Lignite is purchased from a variety of sources in Western Canada, the Western U.S. and overseas. Generally, there is a tendency to purchase from Canadian sources because of lower transportation costs.

8.5 Salt (Halite)

Salt is used in 9 of the sampled wells to a total of 850 tonnes or slightly under 95 tonnes per well. Salt is used primarily to saturate drilling fluids while drilling through salt beds, as a substitute for potash as a shale control inhibitor or as a weighting agent.

One informant advised that salt was a poor substitute for potash and that they did not use it. Certainly our data would suggest that its use is declining. With one exception, salt is only used where potash is not and potash use, as mentioned earlier, is generally rising.

Almost 70 percent of the total salt usage in the sample (580 tonnes) was in five wells drilled in 1980 and the beginning of 1981. Two wells were drilled using salt in 1983, using another 215 tonnes. Since then, only 56 tonnes in two more wells appear in the sample.

What little salt is used is all bought from Windsor or Canada Salt in Nova Scotia. The product is sold in 40 kilogram sacks and sales prices between December 1983 and June 1985 have not varied from 25 cents or 26 cents per kilogram.

8.6 Hematite

Although only found in one well in mud and in one well as a weighting agent in cement, the total weight makes hematite the sixth most common constituent of muds in the sample after barite, bentonite, potash, lignite and chrome lignite, and salt. A number of indications suggest that it could begin to replace barite in the next few years.

Hematite has a number of potential advantages as a weighting agent, chief among which are its specific gravity and its hardness (which has its disadvantages as well). The higher specific gravity (5.3 compared to 4.5 for barite) means that hematite can achieve higher mud weights with fewer suspended solids and therefore allow a higher penetration rate. The hardness of hematite means it is less likely to reduce to hardness of hematite means it is less likely to reduce to colloidal size fines which tend to ruin the mud. This latter point becomes especially important in oil mud which is recycled a number of times. Indeed, this is just one of the reasons why hematite and oil mud are an obvious combination. Hematite is oleophilic so it mixes well and stays in suspension in oil muds. The chief disadvantage of hematite, its abrasiveness, is substantially offset by the lubricating qualities of oil mud and by pre-mixing which eliminates problems with bulk handling.

All these factors would seem to point to increased hematite use as oil mud use increases but other factors may intervene. One is possible substitutes. Ilmenite, for example, would probably be preferred by Baroid since its parent company, N.L., controls the bulk of the world's supply of ilmenite. Another, more general factor is price. At present, the price of hematite is around $225 per tonne landed in Halifax, almost three times the cost of imported barite. Finally, hematite remains difficult to handle due to its abrasiveness on equipment.

Sources for hematite used in Eastern Canada include ore from Brazil and mill scale from steel mills in the United States. Cement companies in particular seem to prefer mill scale and have very particular requirements as to mesh size.

8.7 Sodium Carbonate

Sodium carbonate and its two derivatives, caustic soda and sodium bicarbonate, together make up the seventh most important constituent at 633 tonnes distributed as follows:

Sodium Bicarbonate	77 tonnes in 21 wells
Caustic Soda	464 tonnes in 28 wells
Soda Ash (sodium carbonate)	92 tonnes in 24 wells

Prices for these three commodities make their value in the mud system disproportionate to the amount used. For example, sample sales prices between July 1981 and June 1985 were as follows:

	Low	High	Average	Use (kg)	Total Value
Sodium bicarbonate $/kg	.88	1.13	1.01	77000	$ 77770
Caustic Soda $/kg	.71	1.89	1.45	464000	672800
Soda Ash $/kg	.60	.93	.75	92000	69000

Sources for all sodium carbonate products are the same for all users. All are purchased from local chemical suppliers such as Harrison Crossfield, Van Waters and Rogers, and Eastern Chemical. The ultimate sources are major chemical companies such as CIL, located in Sarnia and Montreal. Occasionally, some of the companies will use offshore sources. For example, Baroid will occasionally purchase chemicals from NOLA (the New Orleans base) if it is coming in with other material.

The key factor in all purchase decisions is price. There are numerous chemical distributors (if only a few producers) in Canada and mud and cement companies will normally shop around looking for the best price.

8.8 Calcium Chloride

Calcium chloride is found in just over half the wells in the sample, at 16,000 kg per well and a total of almost 250,000 kg. Another 57,000 kg of CaCl is found in the cement sample (see p.8-24). Total sales value at the quoted price is around $257,000.

Calcium chloride is used for a variety of purposes in muds, but like lime, is used most frequently in oil muds. It is used as a hole stabilizer.

CaCl is purchased through standard chemical suppliers.

8.9 Calcite

Calcite and its derivatives, lime and quicklime, are found in most wells but in relatively small quantities. Together, they make up less than half of one percent of total minerals in the sample, around 180 tonnes. Total sales value of all calcite products in the sample was $85,393 at quoted prices.

Lime or quicklime account for most of the usage (over 90 percent). They have a variety of uses. Most important from a future market perspective is in oil-base muds as a catalyst for the formation of invert emulsions.

Lime is generally bought through chemical suppliers. One company reported purchasing from Steele Brothers in New Brunswick.

8.10 Gilsonite

Gilsonite is found in only four wells in the sample, at 6500 kg per well, or a total of 26,000 kg. Quoted sales prices indicate a 1985 value of around $59,000.

Gilsonite, an asphalt-like product, has a number of uses including its lubricating qualities and its capacity for hole stabilization. As one informant put it, it 'paves' the hole.

All gilsonite is sourced in Western Canada or the U.S.

8.11 Mica

Mica is used relatively frequently, in 11 wells in the sample but in very small quantities so that total use is just over 37,000 kg with a sales price value of under $34,000. Mica is used as a lost circulation material. The only source quoted was in Quebec.

8.12 Cement

Cement is second only to barite in the weight of material used in a well, at least in the sample observed. As mentioned earlier, however, the sample for cement involves different wells in 16 cases (12 are the same) so any further comparison should be avoided.

Cement is used to anchor casing in the hole which, in turn, is used to isolate the formations from the hole and from each other. A cement 'job' is required each time a new string of casing is inserted (four or five in a well as a rule) or in the case of a 'squeeze' or a 'plug'. The average job for all materials and manpower is reported to be in the range of $50,000 to $60,000. With 8 to 10 jobs on a hole, the total cost can be in the order of $500,000. Even though the largest component by weight is the cement itself, labour and service charges and chemicals both tend to account for a greater share of the cost. Indeed, the total cost of cement and other minerals in the 'average' well in our sample would be less than $90,000. In two instances, however, what were described as 'typical' wells by informants diverged substantially from what was typical in the sample so some care should be taken in comparing these numbers.

In any event, cement is the largest component by weight. All wells in the East Coast offshore use Oilwell Class G cement* and all get it from Havelock, New Brunswick. Class G is simply a very high quality general purpose cement whose qualities are highly predictable and which can be modified in a wide range of predictable ways through the addition of extenders, accelerators, retarders and other materials.

Quality control is of major importance for cement since the consequences of early setting, for example, can be extremely expensive. Apparently, every mill run is slightly different, particularly in its behaviour in hole conditions in the presence of other chemicals. Therefore, it is all the more important that quality be consistent and that batches are properly tested. According to one informant, Havelock took considerable time to 'get it right' and one other suggested that they still have not done so since the cement often contains excessive quantities of fines which create an unduly viscous slurry.

* Classes A and B are lower grade, general purpose 'sidewalk cements'. Classes C to F are specialty cements (faster/ slower settings etc.) and Classes G and H are both very high quality general purpose cements.)

Notwithstanding any complaints, however, all East Coast operations use Havelock because of price considerations. Havelock cement costs $153.00/tonne landed in Halifax. Quebec sources which are reportedly more consistent in quality cost about $40 more per tonne due to shipping costs. To put the matter in perspective, a sales price for cement quoted in mid-1985 was $220/tonne, giving a 50 percent gross margin on Havelock and less than 15 on the Quebec product.

It is useful to put the scale of this market into some perspective. Total use of cement on the east coast offshore from 1980 to mid-1985 would be something over 30,000 tonnes if our sample average is representative. This works out to 6700 tonnes per year, all of which could be produced by Havelock in around 30 days production at a reported rate of 200 to 250 tonnes per day. Given the investment in kiln modifications and testing equipment required to produce Class G cement, it seems improbable that any other Atlantic Canadian supplier could or should get into the market. Indeed, the North Star plant in Corner Brook reportedly considered upgrading to produce Class G, but concluded that it was not economic to do so.

8.13 Other Materials Used in Cement

Numerous other materials are used in cement but most are chemicals rather than industrial minerals. For example, although bentonite is sometimes used in land operations as an extender or filler, it is generally not suitable for use offshore. This is because it has to be used as a dry additive whereas sodium silicate, a more expensive alternative, comes in prehydrated form and can be used in a liquid additive system on the rig. Liquid additive systems are better suited to offshore conditions, and better suited, all things considered, to deep hot wells where high precision is required in the metering and blending of additives.

Another interesting case where price is outweighed by other considerations is the use of silica sand. Although it is used infrequently, it is the second most important material by weight in the cementing operation in those cases where it is used. In very hot conditions (230 degree F or over), cement alone will become brittle as it sets. Silica sand added to the cement forms a less brittle, heat resistant crystal. Such conditions are normally encountered at depths below 4300 meters or so, and in holes where it is desirable to run casing at the bottom and test. Dry holes or dusters involve no test, no casing, only a plug cement and generally no silica sand.

Because silica sand is used in fairly large quantities per hole in relatively few holes, it might be expected that our sample would understate actual use. From discussions with service companies, it is possible that total use would be substantially higher than indicated.

The interesting thing about silica sand is the different sources used by different companies, and the reasons for choosing them. Two of three companies insist on silica 'flour' (finely ground sand) available from Indusmin in St. Jermone, Quebec. The reasons for this are that flour is less abrasive, blends better and, most importantly, because of its greater surface area, it reacts more quickly and fully to produce a stronger result. The cost of silica flour quoted by one informant was a total of $127/tonne, over 70 percent of which was accounted for by transport costs.

One company, however, insists on using silica sand sieved to a standard specification which they purchase from Nova Scotia Sand and Gravel, for which they pay around $110/tonne. Price is not the reason. (For one thing, the reported sales price of silica sand is $400/tonne.) Rather, the company in question feels that the advantages of silica flour are more than offset by the viscosifying effect of the flour. A less viscous slurry flows more readily which means less pumping pressure and, therefore, less risk of formation damage and less risk of leaving uncemented gaps.

The relevance of the above description is simply to illustrate the 'black magic' nature of the business. Each company feels that its method is best. Science allows them to identify the tradeoffs, but the balancing act among the tradeoffs is highly subjective.

The most frequently used industrial mineral other than cement is calcium chloride. It is used in almost all wells (26 of the sample group) at an average of 2.18 tonnes per well. The total contributes less than 20 percent of the total amount of calcium chloride observed in the combined mud and cement samples.

Calcium chloride is used as an accelerator. It is always (and only) used at the top of wells, in particular near the sea floor where cold conditions can substantially delay setting times.

Calcium chloride is normally purchased in 40 or 50 kg. sacks from major chemical companies (such as CIL) through local distributors such as Van Waters and Rogers or Harrison Crossfield. As with other chemicals, the only consideration of any importance is which supplier has the best price.

Hematite is the other mineral found in the sample, although in this case only 2.4 tonnes were observed in 1 out of 28 wells. About the same quantity of ilmenite was found in another well. Again, it seems probable from discussions that the sample has understated hematite use, but the quantity would be so small regardless that it doesn't materially affect any assessment of market prospects.

Hematite is used to weight up the cement slurry when it has to displace a heavy mud system. In a similar manner to the differences with silica sand, different companies like different grades. Some like a fine mesh which mixes better and is less likely to settle out when being moved. Another firm likes a coarser grade because of the viscosity problem created by fine material.

Sources vary. One well service company buys from a mud company. Others purchase mill scale from steel mills in the U.S. No prices were quoted, but since at least one buys directly from a mud company it can be assumed that prices are similar, or in the vicinity of $225/tonne.

8.14 Summary

Table 8.3 summarizes the quantity and cost information described in the foregoing pages. Some caution is indicated, particularly with reference to the price information. The sample is equivalent to about two years average activity out of the past five on the east coast offshore. The amounts were used at varying times over that five year period. The prices are a rough composite gleaned from small bits of information, price lists, published information, and well reports. They represent our best estimate of 1985 costs and have been applied in the table as if all materials were purchased or sold in 1985.

TABLE 8.3
ALL MINERALS FROM CEMENT AND MUD SAMPLES

MINERAL	AMOUNT USED IN SAMPLE	COST PRICE	SALES PRICE	TOTAL VALUE (COST)	TOTAL VALUE (SALES)
BARITE	30966 tonnes	$135/tonne (domestic 1985)	$185/tonne (average 1985)	$4180410	$5728710
BENTONITE	6493 tonnes	$160/tonne	$286/tonne	$1038880	$1856998
CALCIUM CARBONATE (CALCITE)	15520 kg	N/A	$0.70/kg	N/A	$ 10864
AND DERIVATIVES					
LIME	39037 kg	N/A	$0.47/kg	N/A	$ 18347
QUICKLIME	124850 kg	N/A	$0.45/kg	N/A	$ 56182
					$ 85393
CALCIUM CHLORIDE	296094 kg	N/A	$0.87/kg	N/A	$ 257601
CEMENT	10362 tonnes	$153/tonne	$220/tonne	$1585386	$2279640
CHROME LIGNITE	581180 kg	N/A	$1.16/kg	N/A	$ 674168
AND LIGNITE	424705 kg	N/A	$0.47/kg	N/A	$ 223111
					$ 879279
GILSONITE	26050 kg	N/A	$2.26/kg	N/A	$ 58873
GYPSUM	1625 kg	N/A	$0.62/kg	N/A	$ 1007
HEMATITE	817 tonnes	$225/tonne	$250/tonne	$ 183285	$ 204250
MICA	37150 kg	N/A	$0.91/kg	N/A	$ 33806
POTASH	2084 tonnes	$235/tonne	$440/tonne	$ 489780	$ 916960
SALT	850680 kg	N/A	$0.26/kg	N/A	$ 221176
SEPIOLITE	40114 kg	N/A	$0.48/kg	N/A	$ 19254
SILICA SAND	31535 kg	$0.11/kg	$0.40/kg	$ 3486	$ 12614
SODIUM CARBONATE AND DERIVATIVES					
BICARB	7100 kg	N/A	$1.01/kg	N/A	$ 77770
CAUSTIC	464000 kg	N/A	$1.45/kg	N/A	$ 672800
SODA ASH	92000 kg	N/A	$0.75/kg	N/A	$ 69000
					$ 819570

9.0 MAJOR FACTORS AFFECTING THE USE OF MINERALS

Whereas the previous section outlined the range of factors influencing each mineral, this section cuts across a different dimension, focussing on the relative importance of various factors in decisions to use certain minerals or to acquire them from particular sources. The major factors in rough order of importance as far as we can determine are: 1) practice; 2) price; 3) availability; 4) quality; and 5) corporate relations.

9.1 Practice

This term refers to the most basic characterisitc of minerals: what are they used for and why? The discussion reveals something about likely future trends in use and substitutability of various products.

The most significant factor bearing on future practice and the use of all commodities is the potential shift to oil-base muds. All informants took the view that oil based muds were likely to see greater use in the East Coast offshore in future years. Although in international use, oil based muds have become increasingly common including in wild-cat drilling, the East Coast offshore started with water based (because of low and intermittent activity) and has not yet developed the infrastructure to handle oil muds.

Oil muds have certain disadvantages, including toxicity to marine life (but not with mineral oil substituted for diesel), cost of lost circulation (because the system is more expensive) and ability to absorb formation gasses and therefore give less warning of a kick. But the advantages are considerable. Oil muds are more effective at removing rock cuttings, they lubricate better and because they do not use bentonite, there is no filter cake build-up and less chance of stuck pipe (especially in directional drilling). They use half as many products thereby reducing storage on the rig and they are mixed on land at much lower labour cost than for mixing water base muds on the rig. Finally, although more expensive, at $110 per barrel compared to $80 per barrel for water based, the mud system is saved for reuse and can be returned to the mud company for a $70-$80/barrel refund.

Ultimately, the big advantage of oil muds is faster penetration rate and therefore less rig time. One informant indicated that one well had been drilled on the east coast in 20 days less than would have been required with water-base muds. At $250,000 per day, the saving is around $5,000,000, or around five times the cost of the whole mud system.

Oil-base mud is particularly well suited for development drilling. This is because kicks are less common than in exploration drilling (so warning is less critical), because directional drilling is common in development drilling and because the absence of the filter cake avoids blocking productive formations.

One estimate suggests that the market share enjoyed by oil muds is around 15 percent now, but could go to 50 percent after 1986. Should this occur, there will be major savings in the constituents of mud products. There will be less use of products in total because of the recycling and some products will not be used at all in oil muds.

The only mineral which would be added to the list used with oil muds is organophilic clays to replace bentonite. Essentially, an organophilic clay is bentonite or attapulgite treated to make it disperse in oil. The amount used, according to one source, would be 1-2 lb/bbl. compared to bentonite use at around 20 lb/bbl.

It is obvious that, should the offshore market switch to oil muds, our detailed historical picture will provide limited comfort to anyone seeking to estimate future markets. Certainly three of the the four major industrial mineral constituents, bentonite, potash, and lignite will decline dramatically and barite could be replaced in part either by hematite or ilmenite.

Regardless of the potential switch to oil muds, other aspects of current and changing practice should be noted. The relatively low and decreasing use of bentonite is apparently explained by transportation costs from the United States west, awkward handling on offshore rigs, and the avilability of substitutes in the form of organic polymers. In this environment, it is reasonable to expect a corresponding decrease in the use of lignite, chrome lignite and caustic soda. An increase in potash use is a possibility but this basically depends upon individual company preferences.

Practice in cements is relatively stable, at least as far as industrial minerals are concerned. Class G is the only type of cement which will continue to be used and will dominate the total weight of materials in a well. The use of weighting materials and silica sand will continue to be a function of drilling in deep, hot wells. In this regard, shifts to Newfoundland from the Scotian Shelf will probably have a downward effect on total use. Finally, the debate between silica sand and silica flour, while interesting, involves relatively small quantities and values and represents individual company practice which is unlikely to change.

In summary, the total weight of factors bearing on the market could produce the following general results irrespective of changes in total drilling activity:

MINERAL	CHANGE IN USE	MAJOR REASONS
Barite	decrease?	- replaced by hematite or ilmenite in oil muds - recycled in oil muds
Bentonite	decrease	- already declining in offshore use - no use in oil muds
Calcium Carbonate & derivatives	no change?	- lime used in oil muds

MINERAL	CHANGE IN USE	MAJOR REASONS
Calcium Chloride	increase	- extensively used in oil muds
Cement	no change	
Gilsonite	no change	
Gypsum	no change	
Hematite	increase?	- could substitute for barite in oil muds
Lignite and Chrome Lignite	decrease	- use already declining - little use in oil muds
Mica	no change	
Potash	no change?	- no use in oil muds but increasing use in water muds
Salt	decrease	- decreasing use now, possibly some use in oil muds
Sepiolite	no change	- already very little use
Sodium Carbonate & derivatives	decrease	- use declining somewhat - no use in oil muds

9.2 Price

All in all, price seems to have an effect on decisions in the use and composition of muds and cements out of proportion to their apparent importance in the total cost of drilling. In considering bids on mud and cement jobs, price has been the factor most heavily weighted by the operators. A number of informants had observations to offer on this issue, the burden of which seems to be that as long as the choice was among the reputable companies, the total package of products and services was viewed as more or less homogeneous, like a commodity, and price in that case was the only criterion. Anecdotes were related concerning the potential and actual effects of shaving on material usage or quality and the effects on overall costs due to the use of inexperienced (therefore cheaper) personnel.

Since a mistake such as early setting up of cement or, worse, a blow-out can cost millions of dollars and since every day saved drilling is worth over $250,000, it is hard to credit why a purchaser would try to shave small percentages off a package which in total costs from $400,000 to $800,000. However, the reports of this practice were consistent among all informants. At least one thought that practice was changing toward more emphasis on quality of service. If so, this could have implications for the importance of input costs but for now, the watchword time and again seems to be price. Price has some influence on the decision to favour one commodity over another and a great deal to do with the choice of supplier for a given commodity.

In the first instance, two examples are germane. The shift to polymers from bentonite is partly attributable to other factors but clearly what has permitted it is the price parity caused by transportation. An instance where price differentials have apparently inhibited substitution is hematite. Although there are still disadvantages to hematite, it is likely that any movement toward approximate price parity with barite would spur efforts to overcome technical problems.

For certain commodities which are relatively standard, price is by far the main criterion. This is true particularly of chemical type products such as sodium carbonate and derivatives, calcium carbonate and derivatives and calcium chloride. These tend to be relatively valuable products (sales price anywhere from 3 to 10 times as expensive as current sales prices for barite), whose availability within a reasonable time frame is more or less assured.

Other products are also highly price sensitive although quality and availability considerations tend to cloud the picture. The main reason for choice of cement is price. This is also generally true of potash, although the facts are confused by the apparent quality problem or non-availability of Sussex potash. Barite is also very price sensitive but here confusion is added by considerations of security of supply and the distorting effects of local benefits practices.

9.3 Availability

Availability is usually not an issue. Most products are shipped in car-load or container lots which in many cases amount to supply for a year or more. This is true of chemical type products, hematite and silica sand for cement, for example. Most products can be ordered with 30 to 60 days notice and potash from Saskatchewan, for example, normally takes three weeks to get to Saint John's. In a pinch, companies borrow from each other fairly freely.

Security of supply has apparently motivated companies in sourcing barite. At least three of the mud companies have at one time or another established a stake or a first claim on production from an Atlantic Canadian producer. Although this has been partly because domestic prices were much more competitive in the early 1980s, it is consistent with worldwide practice. Mud companies characteristically attempt to secure supplies of barite and occasionally other minerals such as bentonite or ilmenite.

9.4 Quality

Quality is, in one sense, a critical issue; in another, it is of modest consequence. All products must meet API specifications where they have been established and this provides a rigid quality measure. Within the API specifications, however, there is generally fairly broad latitude and companies will often accept less than ideal quality in favour of price or ready availability.

Examples of this include the use of local silica sand in cement, which, although it does not exactly meet a company specification, is close enough to be suitable. The potash foaming problem is another case. In this instance, one company felt that the problem was too severe to warrant going after the price advantage. In two other cases, however, the companies were much less concerned with the quality problem, feeling price was the weightier criterion. Cement is another case where variability within API specification Class G cement is tolerated because of the price advantage.

In some cases, there is no choice. Bentonite is the obvious case where the operators specify Wyoming bentonite and that is simply it. In this particular case, the price and handling advantage has swung to polymers and bentonite has lost ground, but where bentonite is used, the source is consistent.

9.5 Corporate Relations

The companies involved in oil exploration, whether operators, drilling companies or field service companies, are all large and highly diversified, horizontally and vertically. It is of some interest how various corporate relations affect purchase decisions particularly in cases of backward vertical integration where a mud company with an owned supply source may conceivably gain advantage through mechanisms such as transfer pricing.

On the subject of corporate integration, a number of relevant points can be drawn from our research:

1) There are very few cases of integration from oil companies or drilling companies backward to mud or well service companies. In other words, the sources of industrial minerals used in drilling seem to have relatively little to do with corporate relations of oil companies.

2) Although all the mud and well service companies are highly diversified, the ways in which they diversify are immensely variable. For example,

> Halliburton Company, owner of Halliburton Services Ltd., is diversified almost entirely into other engineering services including ownership of Otis Engineering Corp. and Brown and Root Ltd. (an important player in the platform construction business). Of all their subsidiaries, none can be readily identified as mineral producers.
>
> Dresser Industries, owners of Magcobar, Dresser, are much more 'diversely' diversified, although the bulk of their subsidiaries are in the oil field services business. At least seven of Dressers' subsidiaries can be identified as mineral producers or distributers including Aberdeen Barytes Co. Ltd. and Thailand Barite Co.Ltd.
>
> Schlumberger BV, owner of Dowell Schlumberger Canada Inc., whose main business and original business is well logging and secondarily well servicing and completion, are essentially an electronics company who have integrated horizontally and whose main mineral input, cement, does not obviously appear in any of its corporate relations.
>
> NL Industries, owner of Baroid of Canada Ltd., are strongly tied to the minerals industry although primarily lead and titanium. Of particular relevance here is that they mine ilmenite ores and reportedly control much of the world's supply.
>
> Big Three Industries Ltd., owner of Nowsco Well Service Ltd., are horizontally integrated in the oil business in oil well tools, well service and pipelines but none of their subsidiaries is identifiable as a mineral company.

There are a number of other corporate relationships which are relevant here. For example, it is known that Baroid has had an agreement dating back to 1980 with Asarco and Abitibi

Price to purchase barite from Buchans although there is apparently no ownership relationship. Similarly, National Mud apparently has first claim on production from Scottsville. Finally, two items in the Wall Street Journal from March and May 1984 indicate that Halliburton has moved to further integrate by purchasing, through its Imco Services Unit, a 30,000 ton per year Spanish barite operation and a Texan bentonite company.

All in all, the situation is fluid, difficult to pin down and, most important, difficult to draw causal links from. Clearly, a reliable source of barite and, perhaps, bentonite is of importance to the mud companies and they seek to secure it through ownership or agreement. We also know that Baroid has a secure supply of ilmenite and would use it in preference to hematite in oil base muds. And we know that Baroid used to and still does to some degree make its purchases from its parent company's supply base, NOLA, in New Orleans. Just as often, however, corporate relationships produce negative results as the following anecdotes will illustrate.

One mud company reported that the most economical source of chrome lignite is one of its competitors. Notwithstanding the usually paramount significance of price, they do not buy from that source.

Another company reported that a cement company in Western Canada manufactures Class G cement under license from another well services company. Because of the arrangement, the informant company will not buy from the cement manufacturer in question.

In another case, a Canadian well service company not operating in the East Coast offshore is owned by a major chemical company. Consequently, the other service companies avoid purchasing from the chemical company if they can.

In all of these examples, some corporate relationship - not necessarily ownership - led to negative purchase decisions. The reasons cited included 'why should we give profits to our competitors?' and, perhaps more telling, 'if we purchase from them, they will know our selling price'.

In many ways it all does come back to price. Effectiveness in a price competitive business means doing everything to ensure that your competitors do not know quite what you are doing. Therefore, buying from them, from their subsidiaries, or their licensees is simply giving out free information.

9.6 Conclusion

In total, the weight of factors bearing on minerals purchase decisions varies widely from circumstance to circumstance. Clearly, industry practices and technology are the determining factors since they determine which basic materials are bought. Mineral quality as defined by API Specifications is usually an absolute requirement. Corporate relations have a mixed effect. Where vertical integration exists, there is often advantage to purchase from a parent, subsidiary, or affliated company, but it is equally true that integration and other relationships can produce repellant rather than attractive results. All in all, they seem to account for a very small part of the package of reasons for purchase decisions. At the end of the day, price is paramount and this seems unlikely to change in the near future.

10.0 CONCLUSIONS

Table 10.1 recaps total minerals usage in our sample. The reader should recall that the data represent actual minerals usage observed in wells representing about one-third of total activity in the East Coast offshore from 1980 to mid 1985, or about one and a half years of activity. Sales prices are composite 1984/1985 prices from the mud and well service companies to the operators. Input costs are much more difficult to establish with accuracy since that information tends to be carefully guarded. Markups seem to range from as low as 10 percent to as high as 350 percent. Although an 'across the board' figure should not be applied to individual minerals, we are advised that an overall range of 30 to 50 percent is about right. In that case, the input cost of the minerals in Table 10.1 would be around $10 million.

It should be noted that the input cost figure is for finished material at the mud or service company warehouse or dockside. In other words, it includes transportation, wholesaler's value added and processing. Our research does not permit generalizations about what component of the total would represent return to the producer. In the case of barite, producers price seems to be around 60 percent of the price of the delivered, finished product, or about $2.5 million.

While further generalization is very risky, if the barite case were typical, the total received by producers of all minerals in our sample would be $6 million. Since the sample represents one and a half years of activity in the 1980s to date, the annual value to producers would be around $4.0 million.

It is useful to put this figure in perspective. In the Nova Scotia Department of Mines and Energy Annual Report for the year ended March 1984, the reported value of industrial minerals production for the year was $74 million. Aggregate production added another $46 million. In short, the offshore exploration market is a very small part of the total indus-

TABLE 10.1

ALL MINERALS RANKED BY ESTIMATED SALES VALUE

MINERAL	SALES VALUE (observed quantity times composite 1984/85 sales price) $(000s)
BARITE	5,728
CEMENT	2,279
BENTONITE	1,856
POTASH	917
CHROME LIGNITE AND LIGNITE	879
SODIUM CARBONATE AND DERIVATIVES	820
CALCIUM CHLORIDE	257
SALT	221
HEMATITE	204
CALCITE AND DERIVATIVES	85
GILSONITE	59
MICA	34
SEPIOLITE	19
SILICA SAND	12
GYPSUM	1
TOTAL	13,371

trial minerals market and, except for barite, it is of almost no consequence.

It should also be kept in mind that the numbers reported are historical; they represent past activity levels and industry practice. In the future, the sum of factors seem to point to a somewhat reduced market.

Total activity:

- Petroleum drilling activity is highly sensitive to world oil prices and drilling in high-risk, high-difficulty frontier areas is particularly sensitive to price. Most indications are that world oil prices will drop further and not begin to recover in real terms until the 1990s, if then.

- A communication from COGLA in July 1985 estimated East Coast activity at 20 wells per year 1976 to 1989 and 30 wells per year 1990 to 1995, or an average 26 wells per year over the coming decade. By September 1985, a COGLA official was quoted as estimating all East Coast activity at only 10 wells per year to 1990. In short, although development drilling on Hibernia and Sable Island might sustain activity in the 1990s, the next five years promise activity levels about half the level experienced between 1980 and 1985.

Area of activity:

The geographical focus of activity has some bearing on the size and nature of the market. Activity in the past five years has been roughly split between the Grand Banks and the Scotian Shelf. If Hibernia were to be developed first, which looks increasingly probable, the majority of activity would shift to the Grand Banks. The average Venture well drilled to date is around 5700 meters. The average Hibernia well is 4200 meters. Shorter wells naturally use less materials in total. Shallower, cooler, lower pressure wells will use less chrome lignite and less silica sand and weighting agents in cement. Most importantly, they use less barite. In our sample, 8 wells from 3800 to 4200 meters used an average 105 kg of barite per meter of hole; 5 wells from 5200 to 6200 meters used 465kg/m.

Changes in practice:

Changes in industry practice point to less use of minerals in general. Experience allows operators to use mud more precisely tailored to conditions and means less likelihood of losing the mud system. Certain minerals such as bentonite, lignite and chrome lignite are much less commonly used than they were a few years ago. Finally, any shift to oil-base muds will have a major impact. There will be less use of materials in total because the mud will be reused. Except for weighting agents (which could be barite, hematite or ilmenite), small quantities of organophilic clay, and lime and calcium chloride, oil-base muds will use almost no industrial minerals.

Overall, the picture is one of a market which is, at best, flat for the foreseeable future and possibly declining. Total activity will probably be down for the next five years and when it picks up, it will be driven by development drilling - which means drilling in familiar conditions, using oil-base muds and quite conceivably, in the shallower conditions of the Grand Banks.

Prospects for individual commodities are not much more promising. Markets likely to be captured by local products are already being captured to some degree. This is certainly true of cement, lime, salt and barite. Many products such as sodium carbonate derivatives and calcium chloride are produced by chemical processes requiring a much larger scale than Atlantic Canada could support. Other minerals such as bentonite, lignite and chrome lignite are not available in Eastern Canada and their use is declining in any event.

The most important mineral, barite, has limited market prospects. A combination of flat worldwide demand and excess capacity means that prices almost certainly will not approach their 1981 highs in the foreseeable future, which may preclude Atlantic Canadian producers. Moreover, shallower holes, probable reuse of oil mud and possible substitution all point to declining use of barite in the East Coast offshore.

Potash may be more promising since none of the over 2000 tonnes identified in the sample or any other that we know of has been supplied by New Brunswick. This would be a low-risk situation to the producer since any market decline in the Canadian offshore could easily be made up by reorientation to other markets. On the other hand, the quantity relative to total production is very small.

More local limestone products - calcium carbonate, lime, quicklime - could find their way into offshore use, but the markets are very small.

Hematite may have possibilities, but the depressed price of barite will probably set the standard which hematite prices must approach and, at present, they are far out of line. Should hematite become more cost competitive, its advantages might spur research to solve the handling problems. The quantities, however, are fairly modest. Should hematite capture a third of the East Coast market in the 1990s, the total would be around 10,000 tonnes per year.

It is possible that better opportunities may be found by looking at the market from a different perspective. We know of a Nova Scotia lime producer who has proved very successful at grinding barite and building portable grinding machines. The value added, and hence income to Atlantic Canadians beyond the mine gate may be as much or more than what is added at the mine. Conceivably, the processing and preparation of imported raw material is a better prospect than mining our own. In turn, the existence of a local low-cost processor would help make the local product competitive at a future date.

In conclusion, it is worth reiterating again that the offshore exploration market is very modest relative to the scale of most industrial minerals producers. While further investigation may be warranted for some commodities, a realistic approach should consider all of the following. The scale of the East Coast is by itself too small to warrant attention by most producers, but it is evident that a low-cost producer of a quality product can find markets well beyond the home market. The key is low-cost production. What, if anything, can be done to turn local producers into low-cost producers or are there commodities where the nature and location of deposits indicate good prospects for low-cost production? The second key is processing and preparation. Any opportunity should be reviewed in the larger perspective of value added beyond the mine gate.

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APPENDICES

1. Statement of Work

2. List of Agencies Contacted

3. Glossary of Terms

4. API Specifications (Title Page & Table of Contents Only)

    Drilling Fluids
    API SPEC.13A - Oil Well Drilling Fluid Materials
    API RP 13B - Standard Procedure for Testing Drilling Fluids
    API RP 29 - Suggested Procedures for Laboratory Evaluation of Drilling Mud Materials

    Cements
    API Bulletin 10C - Oil Well Cement Nomenclature
    API SPEC.10 - Materials and Testing for Well Cements

5(a) Alphabetical List of Drilling Fluids by Trade Name
 (b) Alphabetical List of Drilling Fluids by Trade Name that Contain Industrial Minerals

6. Well Data

7. Corporate Linkages

Appendix 1 Statement of Work Project No. M1272
DSS File No. -
02GS.23230-5-0004

1. REQUIREMENT:

To carry out on behalf of the Project Authority, specified herein, an in-depth study of the utilization and consumption of industrial minerals by the offshore oil and gas industry, with particular reference to the companies operating off Canada's east coast. The study will also include specific corporate linkages between major oil and gas exploration companies working offshore of Canada's east coast and companies providing industrial minerals to these operations, plus other pertinent factors.

2. BACKGROUND:

A particular goal of the Government of Canada is to correct regional economic imbalance. Energy, Mines and Resources in the 1960's developed mineral agreements with the provinces to stimulate mineral exploration. This initiative eventually came under the umbrella of General Development Agreements administered by and funded in part by the Department of Regional Economic Expansion (DREE). In January 1982 responsibility for regional programs in a particular industrial sector was transferred to the appropriate federal department. New umbrella agreements were developed -- the Federal-Provincial Economic and Regional Development Agreements (ERDA's) -- and new Mineral Development Agreements (MDA's) became subsidiary to the ERDA's.

Under the DREE mineral sub-agreements, the provinces delivered most of the programs. With the new agreements, the federal government and the provinces will fund and deliver their own programs. Under the ERDA approach a wide variety of delivery and funding options are available. The federal or provincial party can "deliver" by letting a contract and paying on performance with funding being 100% federal, 100% provincial.

Approval of geoscience, technology or economic development programs by a federal-provincial management committee, having been proposed by appropriate sub-committees, constitutes permission to proceed to put the program in place. A number of economic development programs have been proposed by EMR for federal delivery. This requisition for services covers one such program, relating specifically to the utilization and consumption of industrial minerals by the offshore oil and gas industry, with particular referene to the companies operating off Canada's east coast.

Successful completion of this study identifies the need for other commodity studies or for province-specific studies.

3. SCOPE OF WORK:

The work shall be conducted in three (3) phases as follows:

3.1 Determine, analyse, explain and illustrate the corporate linkages between/among major oil and gas exploration companies working offshore of Canada's east coast and the companies providing industrial minerals to those operations.

(a) Provide a flow diagram to illustrate the corporate liaisons.

(b) List the industrial minerals used by the offshore oil and gas exploration companies and note commodity trade names. Supply data on quantities and grades used.

Appendix 1 (continued)

(c) Indicate current sources of industrial minerals used by each oil and gas exploration company active offshore.

(d) Describe arrangements for the purchase of industrial minerals, the delivery, handling, storage of these materials.

(e) Determine the production costs of these materials, transportation and delivery costs, and value assigned by the consumer.

3.2 Explain the application of industrial minerals and the complexity of drilling muds by determining which industrial minerals are used, how they are used, why they are used, by describing the interchangeability of industrial minerals particularly in drilling muds and ascertaining what substitute materials are used.

(a) Describe specifications for all materials used particularly in drillings muds.

(b) Describe exact function of each commodity in the total mix.

(c) Describe the processing, preparation, mixing and application of drilling muds.

(d) Determine the quantities of industrial minerals used per foot of hole or per hole and per year by company.

3.3 Address other factors which could advance further information pertinent to the use of industrial minerals by the oil and gas exploration industry, factors not included within (1) and (2) above and of which the selected Contractor is aware by virtue of his knowledge of this field of activity.

Appendix 2 List of Agencies Contacted

Project No. M1272
DSS File No. -
02GS.23230-5-0004

Government Departments

COGLA	Bob Russell Gordon Karg Kim Duffy
Nova Scotia Industrial Benefits Office	Rick Butler Frank Sommerville
Nova Scotia Department of Mines and Energy	Dan Murray
Newfoundland Department of Mines and Energy	Norman Kipnis
Newfoundland Department of Development	Keith Hawley
Newfoundland Petroleum Directorate	Gordon Goss Barry Rogers

Oil Companies

Mobil	Cal Ross Bob Hale
Shell	Alan Hart

Mud Companies

Baroid of Canada	Ken Worobec
Magcobar Dresser	Darrel Graham Dave Satter
National Mud Control	Greg Sutherland
Technifluids	Phil Mitchell

Well Service Companies

Dowell Schlumberger	Dave Woodward
Halliburton	Bill Power Scott Rendell
Nowsco Well Service	Paul Cormier Don Warner

Appendix 3

Project No. M1272
DSS File No. -
02GS.23230-5-0004

From a variety of sources, we have compiled the following lists, which are as complete as possible. However, since drilling fluid products constantly change, and some products are more difficult to identify than others, a full listing is not feasible.

3-1 Alphabetical List of Drilling Fluids by Trade Name

3-2 Alphabetical List of Drilling Fluids by Trade Name that Contain Industrial Minerals

Appendix 3-1

Project No. M1272
DSS File No. -
02GS.23230-5-0004

FULL LISTING OF DRILLING FLUIDS
(LIST.DBF)

TRADE NAME	MINERAL?	CLASS	#
007	YES	THINNERS, DISPERSANTS	1
4M + 4	NO	SHALE CONTROL INHIBITORS	2
A120	NO	CORROSION INHIBITORS	3
ACE BEN	NO	VISCOSIFIERS	4
ACE FLOW	NO	FLOCCULANTS	5
ACE SEAL	NO	LOST CIRCULATION MATERIAL	6
ACE TAN	NO	THINNERS, DISPERSANTS	7
ACESTARCH	NO	FILTRATE REDUCERS	8
ACESTARCH PRESERVATIVE	NO	BACTERICIDES	9
ACONOL X-10	NO	EMULSIFIERS	10
ADD FOAM	NO	FOAMING AGENTS	11
AIR-FOAM	NO	FOAMING AGENTS	12
AKTAFLO-E	NO	EMULSIFIERS	13
AKTAFLO-S	NO	SURFACE ACTIVE AGENTS	14
ALDACIDE	NO	BACTERICIDES	15
ALUMINUM STEARATE	NO	DEFOAMERS	16
AMI-TEC	NO	CORROSION INHIBITORS	17
AMMONIUM BISULFITE	NO	CORROSION INHIBITORS	18
AMMONIUM SULPHATE	NO	SHALE CONTROL INHIBITORS	19
AMPLI-FOAM	NO	FOAMING AGENTS	20
AP 78	NO	VISCOSIFIERS	21
AP-21	NO	FILTRATE REDUCERS	22
AP-EX	NO	FLOCCULANTS	23
AQUA-SPOT	NO	LUBRICANTS	24
AQUA-TEC	NO	CORROSION INHIBITORS	25
AQUAGEL	YES	VISCOSIFIERS	26
AQUARI	NO	VISCOSIFIERS	27
ASPHA-MUL	NO	EMULSIFIERS	28
ATLOSOL, ATLSOL-S	NO	EMULSIFIERS	29
ATTAPULGITE	YES	VISCOSIFIERS	30
AXMDL	NO	LUBRICANTS	31
AZ-32	NO	LUBRICANTS	32
B-FREE	NO	LUBRICANTS	33
B-FREE HEAVY WATE	NO	LUBRICANTS	34
BACBAN	NO	BACTERICIDES	35
BACTERICIDE 400	NO	BACTERICIDES	36
BARA-DEFOAM 1	NO	DEFOAMERS	37
BARABUF	YES	ALKALINITY pH CONTROL	38
BARACARB	YES	WEIGHTING MATERIALS	39
BARACOR A	NO	CORROSION INHIBITORS	40
BARAFLOC	NO	FLOCCULANTS	41
BARAFLOC B	NO	SHALE CONTROL INHIBITORS	42
BARAPAK	NO	VISCOSIFIERS	43
BARAPLUG	NO	FILTRATE REDUCERS	44
BARARESIN	NO	FILTRATE REDUCERS	45
BARAVIS	NO	VISCOSIFIERS	46
BARAZAN	NO	VISCOSIFIERS	47
BARITE	YES	VISCOSIFIERS	48
BARIUM CARBONATE	YES	CALCIUM REMOVERS	49
BARIUM CARBONATE	YES	WEIGHTING MATERIALS	50
BAROID	YES	WEIGHTING MATERIALS	51

FULL LISTING OF DRILLING FLUIDS
(LIST.DBF)

TRADE NAME	MINERAL?	CLASS	#
BAROID ASPHALT	NO	FILTRATE REDUCERS	52
BARRIER	NO	FILTRATE REDUCERS	53
BEN EX	NO	FLOCCULANTS	54
BENGEL	YES	VISCOSIFIERS	55
BENTONITE	YES	VISCOSIFIERS	56
BEX	NO	VISCOSIFIERS	57
BICARBONATE OF SODA	YES	ALKALINITY pH CONTROL	58
BIOMUL	NO	EMULSIFIERS	59
BIOTROL	NO	BACTERICIDES	60
BISPERSE	NO	THINNERS, DISPERSANTS	61
BIT LUBE	NO	LUBRICANTS	62
BORE-TROL	NO	SHALE CONTROL INHIBITORS	63
BOTTOM BED	YES	VISCOSIFIERS	64
BREAK	NO	DEFOAMERS	65
BRIDGE SAL	NO	FILTRATE REDUCERS	66
BRIGHEAL	NO	FILTRATE REDUCERS	67
BRINE GUARD	YES	CORROSION INHIBITORS	68
BRINE SAVER	NO	FILTRATE REDUCERS	69
BRINE STOP	YES	LOST CIRCULATION MATERIAL	70
BRINE THICKENER	NO	VISCOSIFIERS	71
BRINE-OX	NO	CORROSION INHIBITORS	72
BRINE-PAC	NO	CORROSION INHIBITORS	73
BRINEFOAM	NO	FOAMING AGENTS	74
BROCDEFOAM	NO	DEFOAMERS	75
BROMO VIS	NO	VISCOSIFIERS	76
BRONCFLUC	NO	FLOCCULANTS	77
BRONCMUL	NO	EMULSIFIERS	78
BRONCO GEL	YES	VISCOSIFIERS	79
BZC	YES	CORROSION INHIBITORS	80
C-LOX	NO	CORROSION INHIBITORS	81
CAL-SEAL	YES	CEMENT	82
CALCIUM CARBONATE	YES	WEIGHTING MATERIALS	83
CALCIUM CHLORIDE	YES	SHALE CONTROL INHIBITORS	84
CALCIUM CHLORIDE	YES	WEIGHTING MATERIALS	85
CALCIUM LIGNOSULFONATE	NO	THINNERS, DISPERSANTS	86
CAN AM GEL	YES	VISCOSIFIERS	87
CAN FREE	NO	SURFACE ACTIVE AGENTS	88
CANE FIBRE	NO	LOST CIRCULATION MATERIAL	89
CARBO-TROL, A-9	NO	FILTRATE REDUCERS	90
CARBO-FAST	NO	FILTRATE REDUCERS	91
CARBO-GEL	NO	VISCOSIFIERS	92
CARBO-MUL	NO	EMULSIFIERS	93
CARBO-SEA	NO	FILTRATE REDUCERS	94
CARBO-SEAL	NO	LOST CIRCULATION MATERIAL	95
CARBO-TEC L	NO	EMULSIFIERS	96
CARBONOX	YES	THINNERS, DISPERSANTS	97
CARBP-TEC	NO	FILTRATE REDUCERS	98
CARBWATE	YES	WEIGHTING MATERIALS	99
CAUSTIC POTASH	YES	ALKALINITY pH CONTROL	100
CAUSTIC SODA	YES	ALKALINITY pH CONTROL	101
CC-16	NO	THINNERS, DISPERSANTS	102

FULL LISTING OF DRILLING FLUIDS
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TRADE NAME	MINERAL?	CLASS	#
CEASCAL	NO	LOST CIRCULATION MATERIAL	103
CEASTOP	NO	LOST CIRCULATION MATERIAL	104
CEDAR FIBRE	NO	LOST CIRCULATION MATERIAL	105
CEL PAK	NO	FILTRATE REDUCERS	106
CELLEX	NO	FILTRATE REDUCERS	107
CELLOPHANE	NO	LOST CIRCULATION MATERIAL	108
CELLOSEAL	NO	LOST CIRCULATION MATERIAL	109
CELPOL, CELPOL SL	NO	FILTRATE REDUCERS	110
CEMENT, PORTLAND	YES	CEMENT	111
CEMENT, POZZOLAN	YES	CEMENT	112
CFL PLUS	NO	THINNERS, DISPERSANTS	113
CHEM-TROL X	NO	FILTRATE REDUCERS	114
CHEMHIB #3	NO	CORROSION INHIBITORS	115
CHLOROGEL	YES	VISCOSIFIERS	116
CHROME LIGNITE	YES	THINNERS, DISPERSANTS	117
CIB	NO	CORROSION INHIBITORS	118
CLEAN BRIDGE	YES	FILTRATE REDUCERS	119
CMC	NO	FILTRATE REDUCERS	120
COAT 44,45,110,129,415,777,888	NO	CORROSION INHIBITORS	121
COAT-B1400,C1815	NO	CORROSION INHIBITORS	122
CON DET	NO	SURFACE ACTIVE AGENTS	123
CORBON 333	NO	CORROSION INHIBITORS	124
CORE VIS	NO	VISCOSIFIERS	125
CORROSION INHIBITOR	NO	CORROSION INHIBITORS	126
COTTONSEED HULLS	NO	LOST CIRCULATION MATERIAL	127
CROMEX	YES	THINNERS, DISPERSANTS	128
CROMEX PLUS	YES	SEE CROMEX	129
CROSFLOC CFA-70	NO	VISCOSIFIERS	130
CROSFLOC CFA-70,EA-70	NO	SHALE CONTROL INHIBITORS	131
CROSFLOC DFA70, CFN-10, EA 70	NO	FLOCCULANTS	132
CYFLOC	NO	FLOCCULANTS	133
CYNAMER 292	NO	VISCOSIFIERS	134
CYPAN	NO	FILTRATE REDUCERS	135
D 47	NO	DEFOAMERS	136
D-18	YES	WEIGHTING MATERIALS	137
D-31	YES	WEIGHTING MATERIALS	138
D-58	NO	THINNERS, DISPERSANTS	139
D.D.	NO	SURFACE ACTIVE AGENTS	140
DAKOLITE	YES	EMULSIFIERS	141
DAP	NO	SHALE CONTROL INHIBITORS	142
DEFOAM, DEFOAM-2	NO	DEFOAMERS	143
DENSEWATE	YES	WEIGHTING MATERIALS	144
DESCO	NO	THINNERS, DISPERSANTS	145
DETERGENT	NO	SHALE CONTROL INHIBITORS	146
DEXTRID	NO	FILTRATE REDUCERS	147
DF-19	NO	FLOCCULANTS	148
DF-VIS	NO	VISCOSIFIERS	149
DIACEL D	YES	LOST CIRCULATION MATERIAL	150
DIASEAL M	YES	LOST CIRCULATION MATERIAL	151

FULL LISTING OF DRILLING FLUIDS
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TRADE NAME	MINERAL?	CLASS	#
DICK S MUD SEAL	NO	LOST CIRCULATION MATERIAL	152
DIPEL 421	NO	CALCIUM REMOVERS	153
DIRT MAGNET	NO	FLOCCULANTS	154
DOS 3	NO	LUBRICANTS	155
DPL	NO	EMULSIFIERS	156
DRIL-SOL	NO	FLOCCULANTS	157
DRILFOAM	NO	FOAMING AGENTS	158
DRILL AID 405	NO	LUBRICANTS	159
DRILL AID 412	NO	CORROSION INHIBITORS	160
DRILL AID 420, 421	NO	FLOCCULANTS	161
DRILL AID 425	NO	FILTRATE REDUCERS	162
DRILL FAZE	NO	EMULSIFIERS	163
DRILL X	NO	LUBRICANTS	164
DRILLING DETERGENT	NO	SURFACE ACTIVE AGENTS	165
DRILLTEX	NO	VISCOSIFIERS	166
DRILTREAT	NO	EMULSIFIERS	167
DRISCOSE	NO	FILTRATE REDUCERS	168
DRISPAC, DRISPAL SUPER-LOW	NO	FILTRATE REDUCERS	169
DUOVIS	NO	VISCOSIFIERS	170
DURALON	NO	FILTRATE REDUCERS	171
DURATONE	NO	FILTRATE REDUCERS	172
DURENEX	NO	FILTRATE REDUCERS	173
DUROGEL	YES	VISCOSIFIERS	174
DV-33	YES	EMULSIFIERS	175
DWA	NO	EMULSIFIERS	176
DWA 76	NO	SURFACE ACTIVE AGENTS	177
DX-10	NO	SURFACE ACTIVE AGENTS	178
E Z SPOT	NO	LUBRICANTS	179
ECOFILT	NO	FILTRATE REDUCERS	180
ECOVIS	YES	VISCOSIFIERS	181
EMULGO	YES	EMULSIFIERS	182
EMULGO PILL	YES	LOST CIRCULATION MATERIAL	183
EMULSIFIER 115	NO	EMULSIFIERS	184
ENKAPSULATOR	NO	SHALE CONTROL INHIBITORS	185
EW-20	NO	EMULSIFIERS	186
EXPANDED PERLITE	YES	LOST CIRCULATION MATERIAL	187
EZ MUD	NO	VISCOSIFIERS	188
EZ MUL N.T.	NO	EMULSIFIERS	189
EZ-TORQUE	NO	LUBRICANTS	190
F 75, F 78	NO	SURFACE ACTIVE AGENTS	191
FAZELIG	YES	FILTRATE REDUCERS	192
FERRO-CAL	NO	THINNERS, DISPERSANTS	193
FERROWATE	YES	WEIGHTING MATERIALS	194
FIBERTEX	NO	LOST CIRCULATION MATERIAL	195
FILTROL	NO	FILTRATE REDUCERS	196
FL-1	NO	SHALE CONTROL INHIBITORS	197
FL3, FL4	NO	FILTRATE REDUCERS	198
FLOCCULANT	NO	FLOCCULANTS	199
FLOSAL	YES	VISCOSIFIERS	200
FLOXIT	YES	FLOCCULANTS	201

FULL LISTING OF DRILLING FLUIDS
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TRADE NAME	MINERAL?	CLASS	#
FLR-100, FLR SUPERLO	NO	FILTRATE REDUCERS	202
FOAM KONTROL	NO	DEFOAMERS	203
GALENA	YES	WEIGHTING MATERIALS	204
GEL	YES	VISCOSIFIERS	205
GEL-AIR	NO	FOAMING AGENTS	206
GELTHERM	YES	VISCOSIFIERS	207
GELTONE	NO	VISCOSIFIERS	208
GEOGEL	YES	VISCOSIFIERS	209
GILSONITE	YES	LOST CIRCULATION MATERIAL	210
GRAPHITE	YES	LUBRICANTS	211
GREEN BAND	YES	VISCOSIFIERS	212
GYPSUM	YES	SHALE CONTROL INHIBITORS	213
GYPSUM PLASTER	YES	SHALE CONTROL INHIBITORS	214
H-S POLYMER	NO	SHALE CONTROL INHIBITORS	215
H.M.E.	NO	SURFACE ACTIVE AGENTS	216
HARTASIST 20	NO	DEFOAMERS	217
HEAVIWATER I - IV	NO	WEIGHTING MATERIALS	218
HEC	NO	VISCOSIFIERS	219
HEMATITE	YES	WEIGHTING MATERIALS	220
HEVYWATE	YES	WEIGHTING MATERIALS	221
HI FOAM	NO	FOAMING AGENTS	222
HI-TEMP	NO	FILTRATE REDUCERS	223
HIGH YIELD	YES	VISCOSIFIERS	224
HOLEPLUG	YES	LOST CIRCULATION MATERIAL	225
HOWCOBAR	YES	WEIGHTING MATERIALS	226
HR-15, 20	NO	CEMENT RETARDER	227
HR-5	NO	CEMENT RETARDER	228
HT KONTROL	NO	FILTRATE REDUCERS	229
HYDROGEL	YES	VISCOSIFIERS	230
HYDROMITE	YES	CEMENT	231
HYDROVIS	NO	VISCOSIFIERS	232
HYTEX	NO	LOST CIRCULATION MATERIAL	233
IDF-THIN	NO	SEE IDFLOW	234
IDFLOW	NO	SEE FILTROL	235
IMA	YES	FILTRATE REDUCERS	236
IMA CONCENTRATE	NO	DEFOAMERS	237
IMCO BAR	YES	WEIGHTING MATERIALS	238
IMCO BAR-PLUS	YES	WEIGHTING MATERIALS	239
IMCO BRINEGEL	YES	VISCOSIFIERS	240
IMCO CIDE	NO	BACTERICIDES	241
IMCO DEFOAM	NO	DEFOAMERS	242
IMCO EP LUBE	NO	LUBRICANTS	243
IMCO FLAKES	NO	LOST CIRCULATION MATERIAL	244
IMCO FLOC	NO	FLOCCULANTS	245
IMCO FOAMANT	NO	FOAMING AGENTS	246
IMCO FOAMBAN	NO	DEFOAMERS	247
IMCO FREEPIPE	NO	LUBRICANTS	248
IMCO FYBER	NO	LOST CIRCULATION MATERIAL	249
IMCO GEL	YES	VISCOSIFIERS	250
IMCO GELEX	NO	VISCOSIFIERS	251
IMCO HOLE COAT	NO	SHALE CONTROL INHIBITORS	252

FULL LISTING OF DRILLING FLUIDS
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TRADE NAME	MINERAL?	CLASS	#
IMCO IE PAC	YES	SHALE CONTROL INHIBITORS	253
IMCO IRONITE SPONGE	NO	CORROSION INHIBITORS	254
IMCO KEN-CAL	NO	THINNERS, DISPERSANTS	255
IMCO KEN-GEL	YES	VISCOSIFIERS	256
IMCO KENOL CONC	NO	EMULSIFIERS	257
IMCO LIG	YES	THINNERS, DISPERSANTS	258
IMCO LOID	NO	FILTRATE REDUCERS	259
IMCO LUBRIKLEEN	NO	LUBRICANTS	260
IMCO MUD	NO	EMULSIFIERS	261
IMCO MUD OIL	NO	EMULSIFIERS	262
IMCO MYCA	YES	LOST CIRCULATION MATERIAL	263
IMCO NU-DENSE	YES	WEIGHTING MATERIALS	264
IMCO PERMALOID	NO	FILTRATE REDUCERS	265
IMCO PLUG	NO	LOST CIRCULATION MATERIAL	266
IMCO POLYSAFE	NO	FILTRATE REDUCERS	267
IMCO QBT	NO	THINNERS, DISPERSANTS	268
IMCO RD 2000	NO	THINNERS, DISPERSANTS	269
IMCO RD-III	NO	THINNERS, DISPERSANTS	270
IMCO SULF-X II	NO	CORROSION INHIBITORS	271
IMCO SUMPFLOC	NO	FLOCCULANTS	272
IMCO SWS.	NO	EMULSIFIERS	273
IMCO THIN	YES	THINNERS, DISPERSANTS	274
IMCO VC-10	NO	THINNERS, DISPERSANTS	275
IMCO VR	NO	FILTRATE REDUCERS	276
IMCO WOOL	YES	LOST CIRCULATION MATERIAL	277
IMCO X-CORR	NO	CORROSION INHIBITORS	278
IMCO XO2	NO	CORROSION INHIBITORS	279
IMCO-BEST	NO	VISCOSIFIERS	280
IMCO-HYB	YES	VISCOSIFIERS	281
IMCO-KLAY	YES	VISCOSIFIERS	282
IMCO-PHOS	NO	THINNERS, DISPERSANTS	283
IMCO-WATE	YES	WEIGHTING MATERIALS	284
IMCO-XC	NO	VISCOSIFIERS	285
IMPERMEX	NO	FILTRATE REDUCERS	286
INDE PLUG	NO	LOST CIRCULATION MATERIAL	287
INVERMUL N.T.	NO	EMULSIFIERS	288
INVERT 65/35, 70/30, 80/20	NO	EMULSIFIER	289
IPI-WD	NO	SHALE CONTROL INHIBITORS	290
IRONITE CORSTOP	NO	CORROSION INHIBITORS	291
IRONITE SPONGE	NO	CORROSION INHIBITORS	292
J 164	NO	VISCOSIFIERS	293
J274	NO	CORROSION INHIBITORS	294
K-FLO	NO	SURFACE ACTIVE AGENTS	295
K-LIG	YES	FILTRATE REDUCERS	296
KARI	NO	VISCOSIFIERS	297
KC1	YES	SEE POTASSIUM CHLORIDE	298
KELZAN AL, XC	NO	VISCOSIFIERS	299
KENTROL	NO	FILTRATE REDUCERS	300
KIM-MUD	NO	VISCOSIFIERS	301
KUM FREE	NO	LUBRICANTS	302

FULL LISTING OF DRILLING FLUIDS
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TRADE NAME	MINERAL?	CLASS	#
KWIK THIK	YES	VISCOSIFIERS	303
KWIK VIS	NO	VISCOSIFIERS	304
KWIK-SEAL	NO	LOST CIRCULATION MATERIAL	305
KWIKSPOT	NO	LUBRICANTS	306
LD-8	NO	DEFOAMERS	307
LIGCO	YES	FILTRATE REDUCERS	308
LIGCON	YES	FILTRATE REDUCERS	309
LIGNITE	YES	THINNERS, DISPERSANTS	310
LIGNITE, CAUSTISIZED	YES	THINNERS, DISPERSANTS	311
LIME	YES	ALKALINITY pH CONTROL	312
LINTEX	NO	LOST CIRCULATION MATERIAL	313
LIQUI-VIS	NO	VISCOSIFIERS	314
LO LOSS	NO	FILTRATE REDUCERS	315
LO-FOAM	NO	SURFACE ACTIVE AGENTS	316
LO-WATE	YES	WEIGHTING MATERIALS	317
LUBE 106	NO	LUBRICANTS	318
LUBE KOTE	YES	LUBRICANTS	319
LUBETEX	NO	LUBRICANTS	320
LUBRA-BEADS	NO	LUBRICANTS	321
LUBRI-FILM	NO	LUBRICANTS	322
LUBRI-SAL	NO	LUBRICANTS	323
LUBRIGLIDE	NO	LUBRICANTS	324
M129.1	NO	CORROSION INHIBITORS	325
MAGCO CFL	YES	THINNERS, DISPERSANTS	326
MAGCO FOAMCHECK	NO	DEFOAMERS	327
MAGCO INHIBITOR 101,202,303	NO	CORROSION INHIBITORS	328
MAGCO POLY SAL	NO	FILTRATE REDUCERS	329
MAGCO POLYPAC, -ULTRALO	NO	FILTRATE REDUCERS	330
MAGCO THIN X	NO	FILTRATE REDUCERS	331
MAGCO-FEROX	YES	WEIGHTING MATERIALS	332
MAGCO-FGR-OX	YES	WEIGHTING MATERIALS	333
MAGCOBAR	YES	WEIGHTING MATERIALS	334
MAGCOGEL	YES	VISCOSIFIERS	335
MAGCOLUBE	NO	LUBRICANTS	336
MAGCONATE	NO	EMULSIFIERS	337
MAGCONOL	NO	DEFOAMERS	338
MAGCOPHOS	NO	THINNERS, DISPERSANTS	339
MAGCOSAL	YES	WEIGHTING MATERIALS	340
MAGCOSCAV	NO	CORROSION INHIBITORS	341
MAXPAC, MAXPAC SL	NO	FILTRATE REDUCERS	342
MC DEFOAMER	NO	DEFOAMERS	343
MC-500	NO	FILTRATE REDUCERS	344
MD-30	NO	SURFACE ACTIVE AGENTS	345
MF-1	NO	FLOCCULANTS	346
MICA	YES	LOST CIRCULATION MATERIAL	347
MICATEX	YES	LOST CIRCULATION MATERIAL	348
MIL-BAR	YES	WEIGHTING MATERIALS	349
MIL-CEDAR PLUG	NO	LOST CIRCULATION MATERIAL	350
MIL-CLEAN	NO	SURFACE ACTIVE AGENTS	351
MIL-CON	YES	FILTRATE REDUCERS	352

FULL LISTING OF DRILLING FLUIDS
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TRADE NAME	MINERAL?	CLASS	#
MIL-EMULSIFIER	NO	SURFACE ACTIVE AGENTS	353
MIL-FIBER	NO	LOST CIRCULATION MATERIAL	354
MIL-FLO	NO	THINNERS, DISPERSANTS	355
MIL-FREE	NO	LUBRICANTS	356
MIL-GARD, MIL-GARD R	NO	CORROSION INHIBITORS	357
MIL-PLUG	NO	LOST CIRCULATION MATERIAL	358
MIL-POLYMER 302 - 306	NO	VISCOSIFIERS	359
MIL-QUEBRACHO	NO	THINNERS, DISPERSANTS	360
MIL-SOS	NO	SHALE CONTROL INHIBITORS	361
MIL-SPOT	NO	LUBRICANTS	362
MIL-TEMP	NO	THINNERS, DISPERSANTS	363
MILBIO	NO	BACTERICIDES	364
MILCHEM CMC	NO	FILTRATE REDUCERS	365
MILCHEM MD	NO	SURFACE ACTIVE AGENTS	366
MILEX	NO	FLOCCULANTS	367
MILFLAKE	NO	LOST CIRCULATION MATERIAL	368
MILGEL	YES	VISCOSIFIERS	369
MILMICA	YES	LOST CIRCULATION MATERIAL	370
MILSTARCH	NO	FILTRATE REDUCERS	371
MON COSE	NO	FILTRATE REDUCERS	372
MON EX	NO	VISCOSIFIERS	373
MON-PAC	NO	FILTRATE REDUCERS	374
MUD-PAC	NO	CORROSION INHIBITORS	375
MYLO GEL	NO	FILTRATE REDUCERS	376
MYLO-GEL PRESERVATIVE	NO	BACTERICIDES	377
NATURALGEL	YES	VISCOSIFIERS	378
NO-STIK	NO	LUBRICANTS	379
NORMUL	NO	EMULSIFIERS	380
NOXYGEN, NOXYGEN L	NO	CORROSION INHIBITORS	381
NSM	NO	VISCOSIFIERS	382
NUT PLUG	NO	LOST CIRCULATION MATERIAL	383
NYMCEL	NO	FILTRATE REDUCERS	384
NaCl	YES	SEE SALT	385
O S S PILL	NO	LOST CIRCULATION MATERIAL	386
OIL 'N' WATER	NO	EMULSIFIERS	387
OIL FAZE	NO	EMULSIFIERS	388
OILFOS	NO	THINNERS, DISPERSANTS	389
OILMUL-P	NO	EMULSIFIERS	390
OILSPERSE	NO	EMULSIFIERS	391
OILSPOT-P	NO	LUBRICANTS	392
OMC	NO	THINNERS, DISPERSANTS	393
OMG-40	YES	EMULSIFIERS	394
OMNITROL	YES	FILTRATE REDUCERS	395
OS-I, OSI-L	YES	CORROSION INHIBITORS	396
OTTAWA SAND	YES	WEIGHTING MATERIALS	397
PACTEX	NO	VISCOSIFIERS	398
PAPER-OX	NO	LOST CIRCULATION MATERIAL	399
PARAFORMALDEHYDE	NO	BACTERICIDES	400
PELTEX	NO	THINNERS, DISPERSANTS	401
PERMA-FILM	NO	CORROSION INHIBITORS	402
PERMA-LOSE HT	NO	FILTRATE REDUCERS	403

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TRADE NAME	MINERAL?	CLASS	#
PETRO SEAL	NO	LOST CIRCULATION MATERIAL	404
PETROTONE	NO	VISCOSIFIERS	405
PH-10	YES	ALKALINITY pH CONTROL	406
PIPE LAX	NO	SURFACE ACTIVE AGENTS	407
PIPE-GARD	NO	CORROSION INHIBITORS	408
PLASTER	YES	SHALE CONTROL INHIBITORS	409
PLASTER-OF-PARIS	YES	SURFACE ACTIVE AGENTS	410
PLUG-GIT	NO	LOST CIRCULATION MATERIAL	411
POLIDRIL	NO	VISCOSIFIERS	412
POLIHEAL	NO	FILTRATE REDUCERS	413
POLY MUL	NO	EMULSIFIERS	414
POLY PLASTIC	NO	SHALE CONTROL INHIBITORS	415
POLY RX	NO	FILTRATE REDUCERS	416
POLY S	NO	FILTRATE REDUCERS	417
POLY S	NO	SHALE CONTROL INHIBITORS	418
POLY SEAL	NO	LOST CIRCULATION MATERIAL	419
POLY SEC	NO	FLOCCULANTS	420
POLY SEC K D	NO	VISCOSIFIERS	421
POLY-BEN	NO	VISCOSIFIERS	422
POLY-BRIDGE	NO	LOST CIRCULATION MATERIAL	423
POLYBRINE	YES	VISCOSIFIERS	424
POLYGUARD	NO	SHALE CONTROL INHIBITORS	425
POLYMIX	NO	VISCOSIFIERS	426
POLYSPERSE-XHT	NO	THINNERS, DISPERSANTS	427
POLYTEX	NO	FILTRATE REDUCERS	428
POTASH	YES	SHALE CONTROL INHIBITORS	429
POZMIX	YES	CEMENT ACCELERATORS	430
PRE-MIX	YES	VISCOSIFIERS	431
PREMIUM GEL	YES	VISCOSIFIERS	432
PRETEX	NO	SURFACE ACTIVE AGENTS	433
PRIMUL	NO	EMULSIFIERS	434
PRO FIBER	NO	LOST CIRCULATION MATERIAL	435
PRO-3	NO	CORROSION INHIBITORS	436
PRO-EX	NO	VISCOSIFIERS	437
PRO-FILM	NO	CORROSION INHIBITORS	438
PRO-FLOC	NO	FLOCCULANTS	439
PRO-SCALE	NO	CORROSION INHIBITORS	440
PRO-SCAV, A, S	YES	CORROSION INHIBITORS	441
PROTECTOZONE	NO	LOST CIRCULATION MATERIAL	442
Q-BROXIN	NO	THINNERS, DISPERSANTS	443
QB II	NO	THINNERS, DISPERSANTS	444
QUEBRACHO	NO	THINNERS, DISPERSANTS	445
QUICK LIME	YES	ALKALINITY pH CONTROL	446
QUIK FOAM	NO	FOAMING AGENTS	447
QUIK-GEL	YES	VISCOSIFIERS	448
QUIK-MUD	NO	VISCOSIFIERS	449
QUIK-TROL	NO	VISCOSIFIERS	450
R-2264	NO	CORROSION INHIBITORS	451
RAPID FOAM	NO	FOAMING AGENTS	452
RAPID MUD	NO	VISCOSIFIERS	453
RAPIDRIL	NO	FLOCCULANTS	454

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TRADE NAME	MINERAL?	CLASS	#
RAYUAN	NO	THINNERS, DISPERSANTS	455
RAYVAN	YES	EMULSIFIERS	456
REDI-COAT	NO	FLOCCULANTS	457
REDI-DRIL	NO	VISCOSIFIERS	458
REDI-FLOW	NO	FILTRATE REDUCERS	459
REEF CARB	YES	WEIGHTING MATERIALS	460
REEF CARB	YES	LOST CIRCULATION MATERIAL	461
REEF DEFOAM	NO	DEFOAMERS	462
REEF 02	NO	CORROSION INHIBITORS	463
RESINEX	NO	FILTRATE REDUCERS	464
REXOL	NO	SURFACE ACTIVE AGENTS	465
RM-66	NO	SHALE CONTROL INHIBITORS	466
RUF-PLUG	NO	LOST CIRCULATION MATERIAL	467
S.M.R.	NO	VISCOSIFIERS	468
SAFE-MAXFLO	NO	SURFACE ACTIVE AGENTS	469
SAFEGEL	NO	FILTRATE REDUCERS	470
SAFEGUARD 5500, 7000	NO	CORROSION INHIBITORS	471
SALEX	NO	FILTRATE REDUCERS	472
SALINEX	NO	EMULSIFIERS	473
SALT	YES	WEIGHTING MATERIALS	474
SALT GEL	YES	VISCOSIFIERS	475
SALT INHIBITOR	NO	CORROSION INHIBITORS	476
SALT MUD	YES	VISCOSIFIERS	477
SALT WATER GEL	YES	VISCOSIFIERS	478
SANHEAL PILL	NO	LOST CIRCULATION MATERIAL	479
SAPP	NO	THINNERS, DISPERSANTS	480
SAWDUST	NO	LOST CIRCULATION MATERIAL	481
SCALE-CAN	NO	CORROSION INHIBITORS	482
SCAVOX	NO	CORROSION INHIBITORS	483
SE-II	NO	EMULSIFIERS	484
SEA MUD	YES	VISCOSIFIERS	485
SELEC-FLOC	NO	FLOCCULANTS	486
SEPARAN	NO	FLOCCULANTS	487
SEPIOLITE	YES	VISCOSIFIERS	488
SF-100	NO	FILTRATE REDUCERS	489
SHALE KONTROL	NO	SHALE CONTROL INHIBITORS	490
SHALE-GARD	NO	SHALE CONTROL INHIBITORS	491
SHALE-TROL	NO	SHALE CONTROL INHIBITORS	492
SHERSHALE	NO	SHALE CONTROL INHIBITORS	493
SHERSPOT	NO	LUBRICANTS	494
SHERTONE	YES	VISCOSIFIERS	495
SHERWELL X 10	NO	FLOCCULANTS	496
SI-1000	NO	CORROSION INHIBITORS	497
SIGTEX	NO	VISCOSIFIERS	498
SILICA FLOW	YES	CEMENT	499
SIMPLE SEAL	NO	LOST CIRCULATION MATERIAL	500
SKOT FREE	NO	SURFACE ACTIVE AGENTS	501
SLICKPIPE	NO	LUBRICANTS	502
SLIK #5	NO	LUBRICANTS	503
SLUGGITS	YES	LOST CIRCULATION MATERIAL	504
SLUGHEAL	YES	FILTRATE REDUCERS	505

FULL LISTING OF DRILLING FLUIDS
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TRADE NAME	MINERAL?	CLASS	#
SODA ASH	YES	CALCIUM REMOVERS	506
SODIUM BICHROMATE	NO	CORROSION INHIBITORS	507
SODIUM CHLORIDE	YES	SEE SALT	508
SODIUM CHROMATE	NO	CORROSION INHIBITORS	509
SODIUM HEXAMETA PHOSPHATE	NO	CORROSION INHIBITORS	510
SODIUM SULPHATE	NO	CALCIUM REMOVERS	511
SODIUM SULPHITE	NO	CORROSION INHIBITORS	512
SOLTEX	NO	SHALE CONTROL INHIBITORS	513
SOLUBRIGES	NO	LOST CIRCULATION MATERIAL	514
SOLUKLEEN	NO	FILTRATE REDUCERS	515
SOLUVIS	NO	VISCOSIFIERS	516
SOLVAQUIK PILL	NO	LOST CIRCULATION MATERIAL	517
SP-100	NO	FILTRATE REDUCERS	518
SPACER 1000, 3000	NO	THINNERS, DISPERSANTS	519
SPERSENE	NO	THINNERS, DISPERSANTS	520
SPOT	NO	LUBRICANTS	521
SS-100	NO	SHALE CONTROL INHIBITORS	522
SST 200	NO	SHALE CONTROL INHIBITORS	523
STABILHOLE	NO	SHALE CONTROL INHIBITORS	524
STAFLO	NO	FILTRATE REDUCERS	525
STAFLO	NO	VISCOSIFIERS	526
STARCH	NO	BACTERICIDES	527
STARCH	NO	FILTRATE REDUCERS	528
STARLOSE	NO	FILTRATE REDUCERS	529
STUCKBREAKER	NO	LUBRICANTS	530
SUFLO-H35, S30	NO	SURFACE ACTIVE AGENTS	531
SULPHATE OF POTASH	YES	SHALE CONTROL INHIBITORS	532
SUPER FLOC	NO	FLOCCULANTS	533
SUPER GEL, SUPER GEL X	YES	VISCOSIFIERS	534
SUPER LIG	YES	THINNERS, DISPERSANTS	535
SUPER LUBE FLOW	YES	SHALE CONTROL INHIBITORS	536
SUPER VISBESTOS	YES	VISCOSIFIERS	537
SUPER WATE	NO	WEIGHTING MATERIALS	538
SUPER-COL	YES	VISCOSIFIERS	539
SUPER-LUBE-FLOW	YES	LUBRICANTS	540
SURF TREAT	NO	CORROSION INHIBITORS	541
SURF-COTE	NO	SURFACE ACTIVE AGENTS	542
SURFAK E	NO	EMULSIFIERS	543
SURFLO W200, W300	NO	DEFOAMERS	544
T-LESS	NO	See TORQUELESS	545
T-Z PILL	NO	LOST CIRCULATION MATERIAL	546
TACKLE	NO	THINNERS, DISPERSANTS	547
TANN A. THIN, TANNATHIN	YES	THINNERS, DISPERSANTS	548
TECHNI-CAL	YES	WEIGHTING MATERIALS	549
TECHNIFLO	NO	FILTRATE REDUCERS	550
TECHNIFLO HTR	NO	FILTRATE REDUCERS	551
TECHNIGUARD	NO	CORROSION INHIBITORS	552
TECHNIKLEEN	NO	SURFACE ACTIVE AGENTS	553
TECHNIKOTE P	NO	CORROSION INHIBITORS	554
TECHNIMUL	NO	EMULSIFIERS	555
TECHNISEAL	NO	LOST CIRCULATION MATERIAL	556

FULL LISTING OF DRILLING FLUIDS
(LIST.DBF)

TRADE NAME	MINERAL?	CLASS	#
TECHNISURF	NO	SURFACE ACTIVE AGENTS	557
TECHNITROL. TECHNITROL L	NO	FILTRATE REDUCERS	558
TECHNIVIS, HT, XT, R	NO	VISCOSIFIERS	559
TF eX	NO	VISCOSIFIERS	560
THERMO-TROL-50	NO	FILTRATE REDUCERS	561
THERMOGEL	YES	VISCOSIFIERS	562
THERMOTROL	NO	FILTRATE REDUCERS	563
THERMPAC U.L.	NO	FILTRATE REDUCERS	564
THIKQUIK	NO	VISCOSIFIERS	565
THIX	NO	VISCOSIFIERS	566
THIX-PAK	NO	VISCOSIFIERS	567
TORO-TRIM	NO	LUBRICANTS	568
TORQ-KONTROL	NO	LUBRICANTS	569
TORQUE-LESS DII-170	NO	LUBRICANTS	570
TRIMULSO	NO	EMULSIFIERS	571
TRU-OIL	NO	EMULSIFIERS	572
TS301	NO	FILTRATE REDUCERS	573
TSPP	NO	SURFACE ACTIVE AGENTS	574
U.L.S.S.	NO	EMULSIFIERS	575
U66	NO	THINNERS, DISPERSANTS	576
UNI-CAL	NO	THINNERS, DISPERSANTS	577
UNI-DRILL	NO	FILTRATE REDUCERS	578
UNI-STEAM	NO	CORROSION INHIBITORS	579
UNICAL S.E.A.	NO	THINNERS, DISPERSANTS	580
VERTOIL	NO	EMULSIFIERS	581
VG-69	NO	VISCOSIFIERS	582
VISBESTOS	YES	VISCOSIFIERS	583
VISCLEAN	NO	VISCOSIFIERS	584
VISGEL	YES	VISCOSIFIERS	585
VISTEX	NO	VISCOSIFIERS	586
VOSQUIK	NO	VISCOSIFIERS	587
W.O.20 - 23	NO	VISCOSIFIERS	588
W.O.30	YES	LOST CIRCULATION MATERIAL	589
W.O.30	YES	WEIGHTING MATERIALS	590
W.O.35	YES	WEIGHTING MATERIALS	591
W.O.50	YES	LOST CIRCULATION MATERIAL	592
W.O.DEFOAM	NO	DEFOAMERS	593
WALNUT HULLS	NO	LOST CIRCULATION MATERIAL	594
WATE	YES	WEIGHTING MATERIALS	595
WEIGHT SAL	YES	WEIGHTING MATERIALS	596
WEIGHTEX	YES	WEIGHTING MATERIALS	597
WL 100	NO	FILTRATE REDUCERS	598
WONDERSEAL	NO	LUBRICANTS	599
WORKOVER ONE	NO	VISCOSIFIERS	600
WYO-FOAMER	NO	FOAMING AGENTS	601
WYO-GILSOL	YES	SURFACE ACTIVE AGENTS	602
WYO-SURF	NO	LUBRICANTS	603
WYOMING 85	YES	VISCOSIFIERS	604
WYOMING GEL	YES	VISCOSIFIERS	605
X-PEL	NO	SURFACE ACTIVE AGENTS	606
X-PEL-G	YES	SHALE CONTROL INHIBITORS	607

FULL LISTING OF DRILLING FLUIDS
(LIST.DBF)

TRADE NAME	MINERAL?	CLASS	#
XC POLYMER	NO	VISCOSIFIERS	608
XKB-THIN	NO	THINNERS, DISPERSANTS	609
XL DEFOAMER	NO	DEFOAMERS	610
XP-20	YES	THINNERS, DISPERSANTS	611
YPC71	NO	VISCOSIFIERS	612
ZAC 12	NO	CORROSION INHIBITORS	613
ZEOGEL	YES	VISCOSIFIERS	614
ZEQ	NO	VISCOSIFIERS	615
ZINC CARBONATE	YES	CORROSION INHIBITORS	616
ZINC-O-LITE	NO	CORROSION INHIBITORS	617
ZINC-O-MATE	NO	CORROSION INHIBITORS	618
ZINC-O-SORB	NO	CORROSION INHIBITORS	619
ZINC-O-SPONGE	NO	CORROSION INHIBITORS	620
ZING KNOCKOUT	NO	CORROSION INHIBITORS	621
ZONELOCK	NO	LOST CIRCULATION MATERIAL	622
pH KONTROL	NO	ALKALINITY pH CONTROL	623

Appendix 3-2

Project No. M1272
DSS File No. -
02GS.23230-5-0004

OFFSHORE MINERAL PRODUCT USE BY ALPHABETHICAL ORDER

TRADE NAME	DESCRIPTION	CLASS	CLASS TWO	DISTRIBUTOR
007	Lignite, causticized	THINNERS, DISPERSANTS	FILTRATE REDUCERS	ACE DRILLING MUD
AQUAGEL	Morillonite, sodium type	VISCOSIFIERS	FILTRATE REDUCERS	BAROID
ATTAPULGITE	Clay viscosifier for salt water systems	VISCOSIFIERS		most
BARABUF	Magnesium oxide	ALKALINITY pH CONTROL		BAROID
BARACARB	Limestone, ground, CaCO3	WEIGHTING MATERIALS		BAROID
BARITE	Barites, processed (BaSO4)	WEIGHTING MATERIALS		MOST
BARIUM CARBONATE	BaCO3	CALCIUM REMOVERS	WEIGHTING MATERIALS	ALL
BARODENSE	Iron oxide	WEIGHTING MATERIALS		BAROID
BAROID	Barite, barium sulphate (BaSO4)	WEIGHTING MATERIALS		MOST
BENGEL	Bentonite, Wyoming	VISCOSIFIERS		HUGHES DRILLING
BICARBONATE OF SODA	NaHCO3	ALKALINITY pH CONTROL	CALCIUM REMOVERS	ALL
BOTTOM BED	Undersize Canadian bentonite	VISCOSIFIERS		MAGCOBAR
BRINE STOP	Salt (graded)	LOST CIRCULATION MATERIAL		MAGCOBAR
BRONCO GEL	Montmorillonite, sodium	VISCOSIFIERS		BRONCO
CALCIUM CARBONATE	Calcium carbonate	WEIGHTING MATERIALS		ALL
CALCIUM CHLORIDE	Calcium chloride	WEIGHTING MATERIALS		MOST
CAN AM GEL	Bentonite, Wyoming	VISCOSIFIERS		CANAMARA UNITED
CARBONOX	Lignitic humic acid powder	THINNERS, DISPERSANTS		BAROID
CARBWATE	Calcium carbonate	WEIGHTING MATERIALS		BRINE-ADD FLUIDS
CAUSTIC POTASH	KOH	ALKALINITY pH CONTROL		MOST
CAUSTIC SODA	NaOH	ALKALINITY pH CONTROL		ALL
CHROME LIGNITE	Lignite, chrome	THINNERS, DISPERSANTS		TECHNIFLUIDS
CHROMEX PLUS	See CHROMEX I			
CLEAN BRIDGE	Salt particles, sized	FILTRATE REDUCERS	WEIGHTING MATERIALS	MAGCOBBAR
CLOROGEL	Attapulgite clay	VISCOSIFIERS		HUGHES DRILLING
CROMEX I	Lignite, chrome	THINNERS, DISPERSANTS	SHALE CONTROL INHIBITORS	MAGCOBAR
D-18	Ilmenite	WEIGHTING MATERIALS		DOWELL
D-31	Barite	WEIGHTING MATERIALS		DOWELL
DAKOLITE	Lignite	EMULSIFIERS		MOST
DENSEWATE	Hematite	WEIGHTING MATERIALS		HUGHES DRILLING
DIACEL D	Earth, diatomaceous	LOST CIRCULATION MATERIAL		EYO-BEN
DUROGEL	Clay, magnesium silicate, high temperature	VISCOSIFIERS		IMCO SERVICES
ECOVIS	Orgonoclay, invert mud	VISCOSIFIERS		NATIONAL MUD CONTROL
EMULGO	Chalk emulsifier	EMULSIFIERS		BRINE-ADD FLUIDS

OFFSHORE MINERAL PRODUCT USE BY ALPHABETHICAL ORDER

TRADE NAME	DESCRIPTION	CLASS	CLASS TWO	DISTRIBUTOR
EMULGO PILL	Chalk emulsifier with calcium carbonates	LOST CIRCULATION MATERIAL		BRINE-ADD FLUIDS
FAZELIG	Lignite	FILTRATE REDUCERS		MAGCOBAR
FERROWATE	Carbonate, ferrous	WEIGHTING MATERIALS		BRINE-ADD FLUIDS
FLOSAL	Asbestos, shredded	VISCOSIFIERS		MOST
GALENA	Lead sulphate powder	WEIGHTING MATERIALS		MOST
GELTHERM	Sepiolite	VISCOSIFIERS		HUGHES DRILLING
GEOGEL	Clay, sepiolite mud	VISCOSIFIERS		MAGCOBAR
GRAPHITE	Graphite	LUBRICANTS		MOST
GREEN BAND	Bentonite, treated	VISCOSIFIERS		MILCHEM
GYPSUM	Calcium sulphate	SHALE CONTROL INHIBITORS		MOST
HEMATITE	Iron oxide	WEIGHTING MATERIALS		TECHNIFLUIDS
HEVYWATE	Barite	WEIGHTING MATERIALS		HUGHES DRILLING
HIGH YIELD	Bentonite, high yield	VISCOSIFIERS		REEF MUD
HOLEPLUG	Sized sodium bentonite	LOST CIRCULATION MATERIAL		BAROID
HYDROGEL	Bentonite, Wyoming	VISCOSIFIERS		WYO-BEN3
IMA	Salt mud blend	FILTRATE REDUCERS		WYO-BEN
IMCO BAR	Barite	WEIGHTING MATERIALS		IMCO SERVICES
IMCO BAR-PLUS	Barite, blended and hematite	WEIGHTING MATERIALS		IMCO SERVICES
IMCO BRINEGEL	Clay, Attapulgite	VISCOSIFIERS		IMCO SERVICES
IMCO GEL	Sodium montmorillonite	VISCOSIFIERS	FILTRATE REDUCERS	IMCO SERVICES
IMCO IE PAC	Potassium lignite, caustized	SHALE CONTROL INHIBITORS	FILTRATE REDUCERS	IMCO SERVICES
IMCO KEN-GEL	Clay, organophilic	VISCOSIFIERS		IMCO SERVICES
IMCO LIG	Lignite, processed	THINNERS, DISPERSANTS	EMULSIFIERS	IMCO SERVICES
IMCO MYCA	Mica, mineral	LOST CIRCULATION MATERIAL		IMCO SERVICES
IMCO NU-DENSE	Hematite, ground	WEIGHTING MATERIALS		IMCO SERVICES
IMCO SUMPFLOC	Clay flocculant	FLOCCULANTS		IMCO SERVICES
IMCO THIN	Lignite, causticized	THINNERS, DISPERSANTS	EMULSIFIERS	IMCO SERVICES
IMCO WOOL	Mineral wool, fibrous	LOST CIRCULATION MATERIAL		IMCO SERVICES
IMCO-HYB	Bentonite, extended	VISCOSIFIERS		IMCO SERVICES
IMCO-KLAY	Calcium montmorillonite	VISCOSIFIERS	FILTRATE REDUCERS	IMCO SERVICES
IMCO-WATE	Calcium carbonate	WEIGHTING MATERIALS		IMCO SERVICES
KWIK THIK	Benontine, high yield	VISCOSIFIERS		MAGCOBAR
KWIK-WATE	Calcium Carbonate	WEIGHTING MATERIALS		IMCO SERVICES
LIGCO	Lignite	FILTRATE REDUCERS	THINNERS, DISPERSANTS	MILCHEM
LIGCON	Lignite, causticized	FILTRATE REDUCERS	THINNERS, DISPERSANTS	MILCHEM
LIGNITE	Lignite	THINNERS, DISPERSANTS		ALL
LIGNITE, CAUSTISIZED	Lignite, caustisized	THINNERS, DISPERSANTS		ALL
LIME	Hydrated Lime	ALKALINITY pH CONTROL		MOST

OFFSHORE MINERAL PRODUCT USE BY ALPHABETHICAL ORDER

TRADE NAME	DESCRIPTION	CLASS	CLASS TWO	DISTRIBUTOR
LO-WATE	Weight material, acid soluble	WEIGHTING MATERIALS		MAGCOBAR
LUBE KOTE	Graphite	LUBRICANTS		MAGCOBAR
MAGCO-FEROX	Ground hematite	WEIGHTING MATERIALS		MAGCOBAR
MAGCO-FGR-OX	Hematite F203	WEIGHTING MATERIALS		MAGCOBAR
MAGCOBAR	Barium sulphide	WEIGHTING MATERIALS		MAGCOBAR
MAGCOGEL	Bentonite, Wyoming	VISCOSIFIERS		MAGCOBAR
MAGCOSAL	Salt, sized	WEIGHTING MATERIALS		MAGCOBAR
MICA	Mica flake, sized	LOST CIRCULATION MATERIAL		MOST
MICATEX	Mica flakes	LOST CIRCULATION MATERIAL		BAROID
MIL-BAR	Barite	WEIGHTING MATERIALS		MILCHEM
MILGEL	Montmorillonite, sodium type	VISCOSIFIERS		MILCHEM
MILMICA	Mica flakes, nonabrasive	LOST CIRCULATION MATERIAL		MILCHEM
NATURALGEL	Bentonite, undersized	VISCOSIFIERS		MAGCOBAR
OMG-40	Clay, organophilic	EMULSIFIERS		WYO-BEN
PH-10	Butler system magnesium oxide	ALKALINITY pH CONTROL		BRINE ADD FLUIDS
PLASTER	Calcium sulphate	SHALE CONTROL INHIBITORS		ALL
PLASTER-OF-PARIS	CaSO4:1/2H2O	SURFACE ACTIVE AGENTS		ALL
POLYBRINE	Calcium carbonate blend			
POTASH	Potassium chloride (KCL)	SHALE CONTROL INHIBITORS		MOST
PREMIUM GEL	Bentonite, Wyoming	VISCOSIFIERS		CANAMARA UNITED
PRO-SCAV	Sodium sulphite powder	CORROSION INHIBITORS		PROTEC MUD
PRO-SCAV A	Ammonium bisulphite	CORROSION INHIBITORS		PROTEC MUD
PRO-SCAV S	Sodium bisulphite	CORROSION INHIBITORS		PROTEC MUD
QUICK LIME	Calcium Oxide	ALKALINITY pH CONTROL		WYO-BEN
QUIK-GEL	Bentonite, high yield	VISCOSIFIERS		BARPOD
REEF CARB	Calcium carbonate	WEIGHTING MATERIALS	LOST CIRCULATION MATERIAL	REEF MUD
SALT	NaCl	WEIGHTING MATERIALS		ALL
SALT GEL	Clay, attapulgite	VISCOSIFIERS		MAGCOBAR
SALT MUD	Clay, attapulgite	VISCOSIFIERS		ACE DRILLING MUD
SALT WATER GEL	Clay, attapulgite	VISCOSIFIERS		MILCHEM
SEA MUD	Sepiolite, processed	VISCOSIFIERS		WYO-BEN
SEPIOLITE	Clay, thermally processed	VISCOSIFIERS		TECHNIFLUIDS
SLUGGITS	Calcium carbonates, sized	LOST CIRCULATION MATERIAL		BRINE-ADD FLUIDS
SLUGHEAL	Calcite, CaCO	FILTRATE REDUCERS		BRINE-ADD
SODA ASH	Sodium carbonate	CALCIUM REMOVERS		ALL
SULPHATE OF POTASH	K2SO4	SHALE CONTROL INHIBITORS		MOST
SUPER GEL	Bentonite, modified extra high yield Wyoming	VISCOSIFIERS	FLOCCULANTS	CANAMARA UNITED

OFFSHORE MINERAL PRODUCT USE BY ALPHABETHICAL ORDER

TRADE NAME	DESCRIPTION	CLASS	CLASS TWO	DISTRIBUTOR
SUPER GEL X	Clay, high yield	VISCOSIFIERS		CANAMARA UNITED
SUPER LIG	Lignite	THINNERS, DISPERSANTS		CANAMARA UNITED
SUPER LUBE FLOW	Gilsonite	LUBRICANTS	SHALE CONTROL INHIBITORS	MOST
SUPER VISBESTOS	Asbestos, pelletized suspending agent	VISCOSIFIERS		MOST
SUPER-COL	Bentonite, modified high_yield	VISCOSIFIERS		MILCHEM
SUPER-LUBE-FLOW	Gilsonite	LUBRICANTS		MOST
TANNATHIN	Lignite	THINNERS, DISPERSANTS		MAGOBAR
TECHNI-CAL	CaCO3, sized	WEIGHTING MATERIALS		TECHNIFLUIDS
VISBESTOS	Asbestos, shreddes suspending agent	VISCOSIFIERS		MOST
VISGEL	Canadian bentonite	VISCOSIFIERS		MAGCOBAR
W.O. 30	Calcium carbonate	WEIGHTING MATERIALS	LOST CIRCULATION MATERIAL	MILCHEM
W.O. 35	Ferrous carbonate	WEIGHTING MATERIALS		MILCHEM
W.O. 50	Calcium carbonate, graded and polymer	LOST CIRCULATION MATERIAL		MILCHEM
WATE	Calcium carbonate	WEIGHTING MATERIALS		HUGHES DRILLING
WEIGHT SAL	Salt, sized	WEIGHTING MATERIALS		SUPERIOR MUD SALES
WEIGHTEX	CACO3, sized	WEIGHTING MATERIALS		SUPERIOR MUD SALES
WYOMING 85	Bentonite, untreated	VISCOSIFIERS	FILTRATE REDUCERS	CANAMARA UNITED
WYOMING GEL	Montmorillonite, sodium	VISCOSIFIERS	FILTRATE REDUCERS	CANAMARA UNITED
X-PEL-G	Gilsonite, treated	SHALE CONTROL INHIBITORS		MOST
XP-20	Lignite, chrome	THINNERS, DISPERSANTS		MAGCOBAR
ZEOGEL	Clay, attapulgite, powder	VISCOSIFIERS		BAROID
ZINC CARBONATE	Smithsonite, ZnCO3	CORROSION INHIBITORS		ALL

Appendix 4

API SPECIFICATIONS

Project No. M1272
DSS File No. -
02GS.23230-5-0004

DRILLING FLUIDS

4.1 API SPEC 13A - OIL WELL DRILLING FLUID MATERIALS

4.2 API RP 13B - STANDARD PROCEDURE FOR TESTING DRILLING FLUIDS

4.3 API BULLETIN D11 - GLOSSARY FOR DRILLING FLUIDS AND ASSOCIATED TERMS

CEMENTS

4.4 API BULLETIN 10C - OIL WELL CEMENT NOMENCLATURE

4.5 API SPEC 10 - MATERIALS AND TESTING FOR WELL CEMENTS

Appendix 4.1

API Spec 13A
Ninth Edition
March 1983

API
SPECIFICATION
for
OIL-WELL DRILLING-FLUID MATERIALS

OFFICIAL PUBLICATION

REG. U.S. PATENT OFFICE

AMERICAN PETROLEUM INSTITUTE
Washington, D.C.

Issued by
AMERICAN PETROLEUM INSTITUTE
Production Department
211 N. Ervay, Suite 1700
Dallas TX 75201

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Note

This edition supersedes the eighth edition, dated March 1981. It includes revisions adopted at the 1982 Standardization Conference and subsequently approved by letter ballot as reported in Circ PS-1690.

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Foreword

a. This specification is under the jurisdiction of the API Committee on Standardization of Drilling Fluid Materials.

b. The purpose of this specification is to provide standards for materials used in oil-well drilling fluids.

c. Reference is made herein to API RP 13B: *Standard Procedure for Testing Drilling Fluids*, which is also under the jurisdiction of the Committee on Standardization of Drilling Fluid Materials.

Appendix 4.2

API RP 13B
Ninth Edition
May 1982

API

RECOMMENDED PRACTICE

STANDARD PROCEDURE
for
TESTING DRILLING FLUIDS

OFFICIAL PUBLICATION

REG. U.S. PATENT OFFICE

AMERICAN PETROLEUM INSTITUTE
Washington, D.C.

Issued by
AMERICAN PETROLEUM INSTITUTE
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211 N. Ervay, Suite 1700
Dallas, TX 75201

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Note:

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Appendix 4.3

Glossary of Drilling Fluid and Associated Terms

American Petroleum Institute Bulletin D 11, First Edition, December 1965

—A—

Absorption—The penetration or apparent disappearance of molecules or ions of one or more substances into the interior of a solid or liquid. For example, in hydrated bentonite, the planar water that is held between the mica-like layers is the result of absorption.

Acid—Any chemical compound containing hydrogen capable of being replaced by positive elements or radicals to form salts. In terms of the dissociation theory, it is a compound which, on dissociation in solution, yields excess hydrogen ions. Acids lower the pH. Examples of acids or acidic substances are: hydrochloric acid, tannic acid, sodium acid pyrophosphate.

Acidity—The relative acid strength of liquids as measured by pH. A pH value below 7. See pH.

Adhesion—The force which holds together unlike molecules.

Adsorption—A surface phenomenon exhibited by a solid (adsorbent) to hold or concentrate gases, liquids, or dissolved substances (adsorptive) upon its surface, a property due to adhesion. For example, that water held to the outside surface of hydrated bentonite is adsorbed water.

Aeration—The technique of injecting air or gas in varying amounts into a drilling fluid for the purpose of reducing hydrostatic head. Compare Air Cutting.

Agglomerate—The larger groups of individual particles usually originating in sieving or drying operations.

Agglomeration—The grouping of individual particles.

Aggregate—A group of two or more individual particles held together by strong forces. Aggregates are stable to normal stirring, shaking, or handling as powder or a suspension. They may be broken by drastic treatment such as ball milling a powder or by shearing a suspension.

Aggregation—Formation of aggregates. In drilling fluids, aggregation results in the stacking of the clay platelets face to face. The viscosity and gel strength decrease in consequence.

Air Cutting—The inadvertent mechanical incorporation and dispersion of air into a drilling-fluid system. Compare Aeration.

Alkali—Any compound having marked basic properties. See Base.

Alkalinity—The combining power of a base measured by the maximum number of equivalents of an acid with which it can react to form a salt. In water analysis, it represents the carbonates, bicarbonates, hydroxides, and occasionally the borates, silicates, and phosphates in the water. It is determined by titration with standard acid to certain datum points. See *API RP 13B** for specific directions for determination of phenolphthalein (P_f) and methyl orange (M_f) alkalinities of the filtrate in drilling fluids and the alkalinity of the mud itself (P_m). Also see P_f, M_f, and P_m.

Aluminum Stearate—An aluminum salt of stearic acid used as a defoamer. See Stearate.

Analysis, Mud or Drilling-fluid—Examination and testing of the drilling fluid to determine its physical and chemical properties and condition.

Anhydrite—See Calcium Sulfate. Anhydrite is often encountered while drilling. It may occur as thin stringers or massive formations.

Anhydrous—Without water.

Aniline Point—The lowest temperature at which equal volumes of freshly distilled aniline and an oil which is being tested are completely miscible. This test gives an indication of the character (paraffinic, naphthenic, asphaltic, aromatic, mid-continent, etc.) of the oil. The aniline point of diesels or crudes used in drilling mud is also an indication of the deteriorating effect these materials may have on natural or synthetic rubber. The lower the aniline point of an oil the more severe it usually is in damaging rubber parts.

Anion—A negatively charged atom or radical, such as Cl^-, OH^-, $SO_4^=$, etc., in solution of an electrolyte. Anions move toward the anode (positive electrode) under the influence of an electrical potential.

Annular Velocity—The velocity of a fluid moving in the annulus.

Annulus or Annular Space—The space between the drill string and the wall of the hole or casing.

Antifoam—A substance used to prevent foam by greatly increasing the surface tension. Compare Defoamer.

API Gravity—The gravity (weight per unit volume) of crude oil or other related fluids as measured by a system recommended by the American Petroleum Institute. It is related to specific gravity by the following formula:

$$Deg\ API = \frac{141.5}{sp\ gr\ 60\ F/60\ F} - 131.5$$

Apparent Viscosity—The viscosity a fluid appears to have on a given instrument at a stated rate of shear. It is a function of the plastic viscosity and the yield point. The apparent viscosity in centipoises, as determined by the direct-indicating viscometer (which see), is equal to ½ the 600-rpm reading. See also Viscosity, Plastic Viscosity, and Yield Point. In a Newtonian fluid, the apparent viscosity is numerically equal to the plastic viscosity.

Asbestos—Term applied to many fibrous silicate minerals, some forms of which are used in certain drilling fluids.

Asphalt—A natural or mechanical mixture of solid or viscous bitumens found in natural beds or obtained as a residue from petroleum. Asphalt, blends containing asphalt, and altered asphaltic materials (e.g., air-blown, chemically modified, etc.) have been added to certain drilling fluids for such widely different purposes as a component in oil-base muds, lost-circulation material, emulsifier, fluid-loss-control agent, wall-plastering agent, etc.

**Standard Procedure for Testing Drilling Fluids*, American Petroleum Institute, Dallas, Texas, Nov. (1962), 1st Ed.

Atom—According to the atomic theory, the smallest quantity of an element which is capable of entering into chemical combination or that can exist alone.

Atomic Number—The relative weight of an atom of an element as compared with the weight of 1 atom of oxygen, using 16 as the weight of 1 atom of oxygen.

Attapulgite Clay—A colloidal, viscosity-building clay used principally in salt-water muds. Attapulgite, a special fullers earth, is a hydrous magnesium aluminum silicate.

—B—

Balance, Mud—A beam-type balance used in determining mud density. It consists primarily of a base, graduated beam with constant-volume cup, lid, rider, knife edge, and counterweight.

Barite, Barytes, or Heavy Spar—Natural barium sulfate used for increasing the density of drilling fluids. If required, it is usually upgraded to a specific gravity of 4.20. The barite mineral occurs in white, grayish, greenish, and reddish ores or crystalline masses.

Barium Sulfate—$BaSO_4$. See Barite.

Barrel—A volumetric unit of measure used in the petroleum industry consisting of 42 gal.

Barrel Equivalent—A laboratory unit used for evaluating or testing drilling fluids. One gram of material, when added to 350 ml of fluid, is equivalent to 1 lb of material when added to one 42-gal barrel of fluid.

Base—A compound of a metal, or a metal-like group, with hydrogen and oxygen in the proportion to form an OH radical, which ionizes in aqueous solution to yield excess hydroxyl ions. Bases are formed when metallic oxides react with water. Bases increase the pH. Examples are caustic soda and lime.

Base Exchange—The replacement of cations associated with the clay surface by those of another species, e.g., the conversion of sodium clay to calcium clay.

Basicity—pH value above 7. Ability to neutralize or accept protons from acids.

Bentonite—A plastic, colloidal clay, largely made up of the mineral sodium montmorillonite, a hydrated aluminum silicate. For use in drilling fluids, bentonite has a yield in excess of 85 bbl/ton. The generic term "bentonite" is neither an exact mineralogical name, nor is the clay of definite mineralogical composition.

Bicarb—See Sodium Bicarbonate.

Blooie Line—Flow line for air or gas drilling.

Blowout—An uncontrolled escape of drilling fluid, gas, oil, or water from the well caused by the formation pressure being greater than the hydrostatic head of the fluid in the hole.

Boilerhouse—To make up a report on a condition as fact without knowledge of its accuracy. Sometimes referred to as "doghouse."

Brackish Water—Water containing low concentrations of any soluble salts.

Break Circulation—To start movement of the drilling fluid after it has been quiescent in the hole.

Breakout, Oil—Oil that has risen to the surface of the mud which previously had been combined in the mud as emulsion.

Bridge—An obstruction in a well formed by intrusion of subsurface formations.

Brine—Water saturated with or containing a high concentration of common salt (sodium chloride); hence, any strong saline solution containing such other salts as calcium chloride, zinc chloride, calcium nitrate, etc.

Bromine Value—The number of centigrams of bromine which are absorbed by 1 g of oil under certain conditions. This is a test for the degree of unsaturatedness of a given oil.

Brownian Movement—Continuous, irregular motion exhibited by particles suspended in a liquid or gaseous medium, usually as a colloidal dispersion.

BS or BS & W—Base sediment, or base sediment and water.

Buffer—Any substance or combination of substances which, when dissolved in water, produces a solution which resists a change in its hydrogen ion concentration upon the addition of acid or base.

—C—

Cable-tool Drilling—A method of drilling a well by allowing a weighted bit at the bottom of a cable to fall against the formation being penetrated. See Rotary Drilling.

Cake Consistency—According to *API RP 13B*, such notations as "hard," "soft," "tough," "rubbery," "firm," etc., may be used to convey some idea of cake consistency.

Cake Thickness—The measurement of the thickness of the filter cake deposited by a drilling fluid against a porous medium, most often following the standard API filtration test. Cake thickness is usually reported in 32nd of an inch. See Filter Cake and Wall Cake.

Calcium—One of the alkaline earth elements with a valence of 2 and an atomic weight of about 40. Calcium compounds are a common cause of the hardness of water. It is also a component of lime, gypsum, limestone, etc.

Calcium Carbonate—$CaCO_3$. An insoluble calcium salt sometimes used as a weighting material (limestone, oyster shell, etc.), in specialized drilling fluids. It is also used as a unit and/or standard to report hardness.

Calcium Chloride—$CaCl_2$. A very soluble calcium salt sometimes added to drilling fluids to impart special properties, but primarily to increase the density of the fluid phase.

Calcium Contamination—Dissolved calcium ions in sufficient concentration to impart undesirable properties in a drilling fluid, such as flocculation, reduction in yield of bentonite, increase in fluid loss, etc. See also Calcium Sulfate, Gyp, Anhydrite, Lime, Calcium Carbonate.

Calcium Hydroxide—$Ca(OH)_2$. The active ingredient of slaked lime. It is also the main constituent in cement (when wet). This material is referred to as "lime" in field terminology.

Calcium-treated Muds—Calcium-treated muds are drilling fluids to which quantities of soluble calcium compounds have been added or allowed to remain from the formation drilled in order to impart special properties.

Calcium Sulfate—(Anhydrite: $CaSO_4$; plaster of paris: $CaSO_4 \cdot 1/2\ H_2O$; and gypsum: $CaSO_4 \cdot 2H_2O$). Calcium sulfate occurs in muds as a contaminant or may be added to certain muds to impart special properties.

Cation—The positively charged particle in the solution of an electrolyte which, under the influence of an electrical potential, moves toward the cathode (negative electrode). Examples are: Na^+, H^+, NH_4^+, Ca^{++}, Mg^{++}, Al^{+++}.

Caustic or Caustic Soda—See Sodium Hydroxide.

Cave-in—See Sloughing. Cave-in is a severe form of sloughing.

Cavernous Formations—A formation having voluminous voids, usually the result of dissolving by formation waters which may or may not be still present.

CC or Cubic Centimeter—A metric-system unit for the measure of volume. It is essentially equal to the milliliter and commonly used interchangeably. One cubic centimeter of water at room temperature weighs approximately 1 g.

Cement—A mixture of calcium aluminates and silicates made by combining lime and clay while heating. Slaked cement contains about 62.5 percent calcium hydroxide, which is the major source of trouble when cement contaminates mud.

Centipoise (Cp)—A unit of viscosity equal to 0.01 poise. A poise equals 1 g per meter-second, and a centipoise is 1 g per centimeter-second. The viscosity of water at 20 C is 1.005 cp (1 cp = 0.000672 lb/ft-sec).

Centrifuge—A device for the mechanical separation of high specific gravity solids from a drilling fluid. Usually used on weighted muds to recover weight material and discard drill solids. The centrifuge uses high-speed mechanical rotation to achieve this separation, as distinguished from the cyclone-type separator in which the fluid energy alone provides the separating force. See Cyclone and Desander.

Chemicals—In drilling-fluid terminology, a chemical is any material that produces changes in the viscosity, yield point, gel strength, and fluid loss, as well as surface tension.

Chemical Barrel—A container in which various chemicals are mixed prior to addition to the drilling fluid.

Chromate—A compound in which chromium has a valence of 6, e.g., sodium bichromate. Chromate may be added to drilling fluids either directly or as a constituent of chrome lignites or chrome lignosulfonates. In certain areas, chromate is widely used as an anodic corrosion inhibitor, often in conjunction with lime.

Chrome Lignite—Mined lignite, usually leonardite, to which chromate has been added and/or reacted. The lignite can also be causticized with either sodium or potassium hydroxide.

Circulation—The movement of drilling fluid from the suction pit through pump, drill pipe, bit, annular space in the hole, and back again to the suction pit. The time involved is usually referred to as circulation time.

Circulation, Loss of (or Lost)—The result of drilling fluid escaping into the formation by way of crevices or porous media.

Circulation Rate—The volume flow rate of the circulating drilling fluid usually expressed in gallons or barrels per minute.

Clabbered—A slang term commonly used to describe moderate to severe flocculation of mud due to various contaminants; also called "gelled-up."

Clay—A plastic, soft, variously colored earth, commonly a hydrous silicate of alumina, formed by the decomposition of feldspar and other aluminum silicates. See also Attapulgite, Bentonite, High Yield, Low Yield, and Natural Clays. Clay minerals are essentially insoluble in water but disperse under hydration, shearing forces such as grinding, velocity effects, etc., into the extremely small particles varying from submicron to 100-micron sizes.

Clay Extender—Any of several substances, usually high molecular weight organic compounds that, when added in low concentrations to a bentonite or to certain other clay slurries, will increase the viscosity of the system, e.g., polyvinyl acetate-maleic anhydride copolymer. See Low-solids Muds.

CMC—See Sodium Carboxymethylcellulose.

Coagulation—In drilling-fluid terminology, a synonym for flocculation.

Coalescence—The change from a liquid to a thickened curdlike state by chemical reaction. Also the combination of globules in an emulsion caused by molecular attraction of the surfaces.

Cohesion—The attractive force between the same kind of molecules, i.e., the force which holds the molecules of a substance together.

Colloid—A state of subdivision of matter which consists either of single large molecules or of aggregations of smaller molecules dispersed to such a degree that the surface forces become an important factor in determining its properties. The size and electrical charge of the particles determine the different phenomena observed with colloids, e.g., Brownian movement. The sizes of colloids range from 1×10^{-7} cm to 5×10^{-5} cm (0.001 to 0.5 microns) in diameter, although the particle size of certain emulsoids can be in the micron range.

Colloidal Composition—A colloidal suspension containing one or more colloidal constituents.

Colloidal Suspension—Finely divided particles of ultramicroscopic size swimming in a liquid.

Conductivity—A measure of the quantity of electricity transferred across unit area per unit potential gradient per unit time. It is the reciprocal of resistivity. Electrolytes may be added to the drilling fluid to alter its conductivity for logging purposes.

Connate Water—Water that probably was laid down and entrapped with sedimentary deposits, as distinguished from migratory waters that have flowed into deposits after they were laid down.

Consistency—The viscosity of a non-reversible fluid, in poises, for a certain time interval at a given pressure and temperature.

Consistometer—A thickening-time tester having a stirring apparatus to measure the relative thickening time for mud or cement slurries under predetermined temperatures and pressures. See *API RP 10B.*[*]

Contamination—The presence in a drilling fluid of any foreign material that may tend to produce detrimental properties of the drilling fluid.

Continuous Phase—The fluid phase which completely surrounds the dispersed phase that may be colloids, oil, etc.

Controlled Aggregation—A condition in which the clay platelets are maintained stacked by a polyvalent cation, such as calcium, and are deflocculated by use of a thinner.

Conventional Mud—A drilling fluid containing essentially clay and water.

Copolymer—A substance formed when two or more substances polymerize at the same time to yield a product which is not a mixture of separate polymers but a complex having properties different from either polymer alone. See Polymer. Examples are polyvinyl acetate-maleic anhydride copolymer (clay extender and selective flocculant), acrylamide-carboxylic acid copolymer (total flocculant), etc.

Corrosion—The adverse chemical alteration on a metal or the eating away of the metal by air, moisture, or chemicals; usually an oxide is formed.

Crater—The formation of a large funnel-shaped cavity at the top of a hole resulting from a blowout or occasionally from caving.

Creaming of Emulsions—The settling or rising of the particles of the dispersed phase of an emulsion as observed by a difference in color shading of the layers formed. This can be either upward or downward creaming, depending upon the relative densities of the continuous and dispersed phases.

Created Fractures—Induced fractures by means of hydraulic or mechanical pressure exerted on the formation.

Cuttings—Small pieces of formation that are the result of the chipping and/or crushing action of the bit. See Samples.

Cycle Time, Drilling-fluid—The time of a cycle, or down the hole and back, is the time required for the pump to move the drilling fluid in the hole. The cycle in minutes equals the barrels of mud in the hole divided by barrels per minute.

Cyclone—A device for the separation of various particles from a drilling fluid, most commonly used as a desander. The fluid is pumped tangentially into a cone, and the fluid rotation provides enough centrifugal force to separate particles by mass weight. See Centrifuge.

—D—

Darcy—A unit of permeability. A porous medium has a permeability of 1 darcy when a pressure of 1 atm on a sample 1 cm long and 1 sq cm in cross section will force a liquid of 1-cp viscosity through the sample at the rate of 1 cc per sec.

Deflocculation—Breakup of flocs of gel structures by use of a thinner.

Defoamer or Defoaming Agent—Any substance used to reduce or eliminate foam by reducing the surface tension. Compare Antifoam.

Dehydration—Removal of free or combined water from a compound.

Diesel-oil Plug—See Gunk Plug.

Deliquesence—The liquifaction of a solid substance due to the solution of the solid by adsorption of moisture from the air, e.g., calcium chloride.

Density—Matter measured as mass per unit volume expressed in pounds per gallon (ppg), pounds per square inch per 1,000 ft of depth (psi/1,000 ft), and pounds per cubic ft (lb/cu ft). Density is commonly referred to as "weight."

Desander—See Cyclone.

Diatomaceous Earth—An infusorial earth composed of siliceous skeletons of diatoms and being very porous. Sometimes used for combatting lost circulation and as an additive to cement; also has been added to special drilling fluids for a particular purpose.

Differential Pressure—The difference in pressure between the hydrostatic head of the drilling-fluid column and the formation pressure at any given depth in the hole. It can be positive, zero, or negative with respect to the hydrostatic head.

Differential-pressure (Wall) Sticking—Sticking which occurs because part of the drill string (usually the drill collars) becomes embedded in the filter cake resulting in a non-uniform distribution of pressure around the circumference of the pipe. The conditions essential for sticking require a permeable formation and a pressure differential across a nearly impermeable filter cake and drill string.

Diffusion—The spreading, scattering, or mixing of a material (gas, liquid, or solid).

Dilatant Fluid—A dilatant or inverted plastic fluid is usually made up of a high concentration of well-dispersed solids which exhibits a non-linear consistency curve passing through the origin. The apparent viscosity increases instantaneously with increasing rate of shear. The yield point, as determined by conventional calculations from the direct-indicating viscometer readings, is negative; however, the true yield point is zero.

Diluent—Liquid added to dilute or thin a solution.

Direct-indicating Viscometer—See Viscometer, Direct-indicating.

Dispersant—Any chemical which promotes dispersion of the dispersed phase.

Dispersed Phase—The scattered phase (solid, liquid, or gas) of a dispersion. The particles are finely divided and completely surrounded by the continuous phase.

Dispersion (of Aggregates)—Subdivision of aggregates. Dispersion increases the specific surface of the particle; hence results in an increase in viscosity and gel strength.

Dispersoid—A colloid or finely divided substance.

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[*] *Recommended Practice for Testing Oil-well Cements and Cement Additives*, American Petroleum Institute, Dallas, Texas, March (1965), 14th Ed.

Dissociation—The splitting up of a compound or element into two or more simple molecules, atoms, or ions. Applied usually to the effect of the action of heat or solvents upon dissolved substances. The reaction is reversible and not as permanent as decomposition; i.e., when the solvent is removed, the ions recombine.

Distillation—Process of first vaporizing a liquid and then condensing the vapor into a liquid (the distillate), leaving behind non-volatile substances, the total solids of a drilling fluid. The distillate is the water and/or oil content of a fluid.

Dog-leg—The "elbow" caused by a sharp change of direction in the well bore.

Drilling In—The operation during the drilling procedure at the point of drilling into the pay formation.

Drilling Mud or Fluid—A circulating fluid used in rotary drilling to perform any or all of various functions required in the drilling operation.

Drilling Out — The operation during the drilling procedure when the cement is drilled out of the casing before further hole is made or completion attempted.

Drill-stem Test (DST) — A test to determine whether oil and/or gas in commercial quantities has been encountered in the well bore.

Dynamic—The state of being active or in motion; opposed to static.

—E—

Electric Logging—Electric logs are run on a wire line to obtain information concerning the porosity, permeability, fluid content of the formations drilled, and other information. The drilling-fluid characteristics may need to be altered to obtain good logs.

Electrolyte — A substance which dissociates into charged positive and negative ions when in solution or a fused state and which will then conduct an electric current. Acids, bases, and salts are common electrolytes.

Emulsifier or Emulsifying Agent — A substance used to produce an emulsion of two liquids which do not mix. Emulsifiers may be divided, according to their behavior, into ionic and non-ionic agents. The ionic types may be further divided into anionic, cationic, and amphoteric, depending upon the nature of the ion-active groups.

Emulsion—A substantially permanent heterogeneous liquid mixture of two or more liquids which do not normally dissolve in each other but which are held in suspension or dispersion, one in the other, by mechanical agitation or, more frequently, by adding small amounts of substances known as emulsifiers. Emulsions may be mechanical, chemical, or a combination of the two. They may be oil-in-water or water-in-oil types.

Emulsoid—Colloidal particles which take up water.

End Point—Indicates the end of some operation or when a definite change is observed. In titration this change is frequently a change in color of an indicator which has been added to the solution or the disappearance of a colored reactant.

Engineer, Mud or Drilling-fluid—One versed in drilling fluids whose duties are to manage, carry through, and maintain the various types of oil-well mud programs.

EP Additive—See Extreme-pressure Lubricant.

Epm or Equivalents per Million—Unit chemical weight of solute per million unit weights of solution. The epm of a solute in solution is equal to the ppm (parts per million) divided by the equivalent weight. Refer also to Ppm.

Equivalent Circulating Density—For a circulating fluid, the equivalent circulating density in lb/gal equals the hydrostatic head (psi) plus the total annular pressure drop (psi) divided by the depth (ft) and by 0.052.

Equivalent Weight or Combining Weight — The atomic or formula weight of an element, compound, or ion divided by its valence. Elements entering into combination always do so in quantities proportional to their equivalent weights.

Extreme-pressure Lubricant — Additives which, when added to the drilling fluid, impart lubrication to the bearing surfaces when subjected to extreme pressure conditions.

—F—

Fault—Geological term denoting a formation break, upward or downward, in the subsurface strata. Faults can significantly affect the area mud and casing programs.

Fermentation—Decomposition process of certain organic substances, e. g., starch in which a chemical change is brought about by enzymes, bacteria, or other micro-organisms. Often referred to as "souring."

Fiber or Fibrous Materials—Any tough stringy material used to prevent loss of circulation or to restore circulation. In field use, fiber generally refers to the larger fibers of plant origin.

Filling the Hole—Pumping drilling fluid continuously or intermittently into the well bore to maintain the fluid level in the hole near the surface. The purpose is to avoid danger of blowout, water intrusion, and/or caving of the well bore, e.g., as the pipe is withdrawn.

Fillup Line—The line through which fluid is added to the hole.

Filter Cake — The suspended solids that are deposited on a porous medium during the process of filtration. See also Cake Thickness.

Filter-cake Texture—The physical properties of a cake as measured by toughness, slickness, and brittleness. See also Cake Consistency.

Filter-cake Thickness — A measurement of the solids deposited on filter paper in 32nd of an inch during the standard 30-min API filter test. See Cake Thickness. In certain areas the filter-cake thickness is a measurement of the solids deposited on filter paper for a 7½-min duration.

Filter Loss—See Fluid Loss.

Filter Paper—Porous unsized paper for filtering liquids. API filtration test specifies one thickness of 9-cm filter paper Whatman No. 50, S&S No. 576, or equivalent.

Filter Press—A device for determining fluid loss of a drilling fluid having specifications in accordance with *API RP 13B*.

Filtrate—The liquid that is forced through a porous medium during the filtration process. For test, see Fluid Loss.

Filtration — The process of separating suspended solids from their liquid by forcing the latter through a porous medium. Two types of fluid filtration occur in a well: dynamic filtration while circulating, and static filtration when at rest.

Filtration Qualities—The filtration characteristics of a drilling mud. Generally these qualities are inverse to the thickness of the filter cake deposited on the face of a porous medium and the amount of filtrate allowed to escape from the drilling fluid into or through the medium.

Filtration Rate—See Fluid Loss.

Fishing—Operations on the rig for the purpose of retrieving from the well bore sections of pipe, collars, junk, or other obstructive items which are in the hole.

Flat Gel — A condition wherein the 10-min gel strength is substantially equal to the initial gel strength.

Flipped—When the opposite occurs of what is intended in a drilling fluid. In an invert water-in-oil emulsion, the emulsion is said to be flipped when the continuous and dispersed phases reverse.

Flocculates—Groups of aggregates or particles in suspension subject to being broken up by normal shaking and stirring and reforming on standing.

Flocculating Agent — Substances, such as most electrolytes, some polysaccharides, certain natural or synthetic polymers, that bring about the thickening of the consistency of a drilling fluid. In Bingham plastic fluids, the yield point and gel strength increase.

Flocculation — Loose association of particles in lightly bonded groups, non-parallel association of clay platelets. In concentrated suspensions, such as drilling fluids, flocculation results in gelation. In some drilling fluids, flocculation may be followed by irreversible precipitation of colloids and certain other substances from the fluid, e.g., red beds.

Flocs—See Flocculates.

Fluid—A fluid is a substance readily assuming the shape of the container in which it is placed. The term includes both liquids and gases. It is a substance in which the application of every system of stresses (other than hydrostatic pressure) will produce a continuously increasing deformation without any relation between time rate of deformation at any instant and the magnitude of stresses at that instant. Drilling fluids are usually Newtonian and plastic, seldom pseudoplastic, and rarely dilatant fluids.

Fluid Flow—The state of fluid dynamics of a fluid in motion is determined by the type of fluid (e.g., Newtonian, plastic, pseudoplastic, dilatant), the properties of the fluid such as viscosity and density, the geometry of the system, and the velocity. Thus, under a given set of conditions and fluid properties, the fluid flow can be described as plug flow, laminar (called also Newtonian, streamline, parallel, or viscous) flow, or turbulent flow. See above terms and Reynolds number.

Fluidity—The reciprocal of viscosity. The measure of rate with which a fluid is continuously deformed by a shearing stress. Ease of flowing.

Fluid Loss—Measure of the relative amount of fluid lost (filtrate) through permeable formations or membranes when the drilling fluid is subjected to a pressure differential. For standard API filtration-test procedure, see *API RP 13B.*

Fluorescence—Instantaneous re-emission of light of a greater wave length than that light originally absorbed.

Foam—A foam is a two-phase system, similar to an emulsion, where the dispersed phase is a gas or air.

Foaming Agent—A substance that produces fairly stable bubbles at the air-liquid interface due to agitation, aeration, or ebullition. In air or gas drilling, foaming agents are added to turn water influx into aerated foam. This is commonly called "mist drilling"

Formation Damage—Damage to the productivity of a well resulting from invasion into the formation by mud particles or mud filtrates. Asphalt from crude oil will also damage some formations. See Mudding Off.

Formation Sensitivity — The tendency of certain producing formations to adversely react with invading mud filtrates.

Functions of Drilling Fluids—The most important function of drilling fluids in rotary drilling is to bring cuttings from the bottom of the hole to the surface. Some other important functions are: control subsurface pressures, cool and lubricate the bit and drill string, deposition of an impermeable wall cake, etc.

Funnel Viscosity—See Marsh Funnel Viscosity.

—G—

Galena—Lead sulfide (PbS). Technical grades (specific gravity about 7) are used for increasing the density of drilling fluids to points impractical or impossible with barite.

Gas Cut—Gas entrained by a drilling fluid. See Air Cutting.

Gel — A state of a colloidal suspension in which shearing stresses below a certain finite value fail to produce permanent deformation. The minimum shearing stress that will produce permanent deformation is known as the shear or gel strength of the gel. Gels commonly occur when the dispersed colloidal particles have a great affinity for the dispersing medium, i.e., are lyophilic. Thus gels commonly occur with bentonite in water. For their measurement, see Gel Strength, Initial and 10-min.

Gel—A term used to designate highly colloidal, high-yielding, viscosity-building commercial clays, such as bentonite and attapulgite clays.

Gelation—Association of particles to form a continuous structure.

Gel Cement—Cement having a small to moderate percentage of bentonite added as a filler and/or to reduce the slurry weight. See Gunk Plug.

Gelled Up—Oil-field jargon usually referring to any fluid with high gel strength and/or highly viscous properties. Often a state of severe flocculation.

GEL STRENGTH—The ability or the measure of the ability of a colloid to form gels. Gel strength is a pressure unit usually reported in lb/100 sq ft. It is a measure of the same interparticle forces of a fluid as determined by the yield point except that gel strength is measured under static conditions, yield point under dynamic conditions. The common gel-strength measurements are initial and the 10-min gels (which see). See also Shear and Thixotropy.

GEL STRENGTH, INITIAL—The measured initial gel strength of a fluid is the maximum reading (deflection) taken from a direct-reading viscometer after the fluid has been quiescent for 10 sec. It is reported in lb/100 sq ft. See *API RP 13B* for details of test procedure.

GEL STRENGTH, 10-MIN—The measured 10-min gel strength of a fluid is the maximum reading (deflection) taken from a direct-reading viscometer after the fluid has been quiescent for 10 min. The reading is reported in lb/100 sq ft. See *API RP 13B* for details of test procedure.

GPG OR GRAINS PER GALLON—Ppm (which see) equals gpg × 17.1.

GRAVITY, SPECIFIC—The weight of a particular volume of any substance compared to the weight of an equal volume of water at a reference temperature. For gases, air is usually taken as the reference substance, although hydrogen is sometimes used.

GREASING OUT—Certain organic substances, usually fatty-acid derivatives, which are added to drilling fluids as emulsifiers, e.p. lubricants, etc., may react with such ions as calcium and magnesium that are in or will subsequently come into the system. An essentially water-insoluble greasy material separates out.

GUM—Any hydrophilic plant polysacchrides or their derivatives which, when dispersed in water, swell to produce a viscous dispersion or solution. Unlike resins, they are soluble in water and insoluble in alcohol.

GUMBO—Any relatively sticky formation, such as clay, encountered in drilling.

GUAR GUM—A naturally occurring hydrophilic polysaccharide derived from the seed of the guar plant. The gum is chemically classified as a galactomannan. Guar gum slurries made up in clear fresh or brine water possess pseudoplastic flow properties.

GUNK PLUG—A slurry in crude or diesel oil containing any of the following materials or combinations: bentonite, cement, attapulgite, and guar gum (never with cement). Used primarily in combatting lost circulation. The plug may or may not be squeezed.

GUNNING THE PITS—Mechanical agitation of the drilling fluid in a pit by means of a mud gun, electric mixer, or agitator.

GYP OR GYPSUM—See Calcium Sulfate. Gypsum is often encountered while drilling. It may occur as thin stringers or massive formations.

—H—

HARDNESS (OF WATER)—The hardness of water is due principally to the calcium and magnesium ions present in the water and is independent of the accompanying acid ions. The total hardness is measured in terms of parts per million of calcium carbonate or calcium and sometimes equivalents per million of calcium. For hardness tests, see *API RP 13B*.

HEAVING—The partial or complete collapse of the walls of a hole resulting from internal pressures due primarily to swelling from hydration or formation gas pressures. See Sloughing.

HETEROGENEOUS—A substance that consists of more than one phase and is not uniform, such as colloids, emulsions, etc. It has different properties in different parts.

HIGH-pH MUD—A drilling fluid with a pH range above 10.5. A high-alkalinity mud.

HIGH-YIELD DRILLING CLAY—A classification given to a group of commercial drilling-clay preparations having a yield of 35 to 50 bbl/ton and intermediate between bentonite and low-yield clays. High-yield drilling clays are usually prepared by peptizing low-yield calcium montmorillonite clays or, in a few cases, by blending some bentonite with the peptized low-yield clay.

HOMOGENEOUS—Of uniform or similar nature throughout; or a substance or fluid that has at all points the same property or composition.

HOPPER, JET—See Mud-mixing Devices. A device to hold or feed drilling-mud additives.

HUMIC ACID—Organic acids of indefinite composition in naturally occurring leonardite lignite. The humic acids are the most valuable constituent. See Lignin.

HYDRATE—A substance containing water combined in the molecular form (such as $CaSO_4 \cdot 2H_2O$). A crystalline substance containing water of crystallization.

HYDRATION—The act of a substance to take up water by means of absorption and/or adsorption.

HYDROGEN ION CONCENTRATION—A measure of the acidity or alkalinity of a solution, normally expressed as pH. See pH.

HYDROLYSIS—Hydrolysis is the reaction of a salt with water to form an acid and base. For example, soda ash (Na_2CO_3) hydrolyzes basically, and hydrolysis is responsible for the increase in the pH of water when soda ash is added.

HYDROMETER—A floating instrument for determining the specific gravity or density of liquids, solutions, and slurries. A common example is the Mudwate hydrometer used to determine the density of mud.

HYDROPHILE—A substance usually in the colloidal state or an emulsion, which is wetted by water; i.e., it attracts water or water adheres to it.

HYDROPHILIC—A property of a substance having an affinity for water or one that is wetted by water.

HYDROPHILIC-LIPOPHILIC BALANCE (HLB)—The hydrophilic-lipophilic balance (HLB) is one of the most important properties of emulsifiers. It is an expression of the relative attraction of an emulsifier for water and oil, determined largely by the chemical composition and ionization characteristics of a given emulsifier. The HLB of an emulsifier is not directly related to solubility, but it determines the type of an emulsion that tends to be formed. It is an indication of the behavior characteristics and not an indication of emulsifier efficiency.

Hydrophobe—A substance, usually in the colloidal state, not wetted by water.

Hydrophobic—Descriptive of a substance which repels water.

Hydrostatic Head—The pressure exerted by a column of fluid, usually expressed in pounds per square inch. To determine the hydrostatic head at a given depth in psi, multiply the depth in feet by the density in pounds per gallon by 0.052.

Hydroxide — A designation that is given for basic compounds containing the OH^- radical. When these substances are dissolved in water, they increase the pH of the solution. See Base.

Hygroscopic—The property of a substance enabling it to absorb water from the air.

—I—

Indicator—Substances in acid-base titrations which, in solution, change color or become colorless as the hydrogen ion concentration reaches a definite value, these values varying with the indicator. In other titrations such as chloride, hardness, and other determinations, these substances change color at the end of the reaction. Common indicators are phenolphthalein, potassium chromate, etc.

Inhibited Mud—A drilling fluid having an aqueous phase with a chemical composition that tends to retard and even prevent (inhibit) appreciable hydration (swelling) or dispersion of formation clays and shales through chemical and/or physical means. See Inhibitor (Mud).

Inhibitor (Corrosion) — Any agent which, when added to a system, slows down or prevents a chemical reaction or corrosion. Corrosion inhibitors are used widely in drilling and producing operations to prevent corrosion of metal equipment exposed to hydrogen sulfide, carbon dioxide, oxygen, salt water, etc. Common inhibitors added to drilling fluids are filming amines, chromates, and lime.

Inhibitor (Mud)—Substances generally regarded as drilling-mud contaminants, such as salt and calcium sulfate, are called inhibitors when purposely added to mud so that the filtrate from the drilling fluid will prevent or retard the hydration of formation clays and shales.

Initial Gel—See Gel Strength, Initial.

Interfacial Tension—The force required to break the surface between two immiscible liquids. The lower the interfacial tension between the two phases of an emulsion, the greater the ease of emulsification. When the values approach zero, emulsion formation is spontaneous. See Surface Tension.

Interstitial Water—Water contained in the interstices or voids of formations.

Invert Oil-emulsion Mud—An invert emulsion is a water-in-oil emulsion where fresh or salt water is the dispersed phase and diesel, crude, or some other oil is the continuous phase. Water increases the viscosity and oil reduces the viscosity.

Iodine Number—The number indicating the amount of iodine absorbed by oils, fats, and waxes, giving a measure of the unsaturated linkages present. Generally, the higher the iodine number, the more severe the action of the oil on rubber.

Ion—Acids, bases, and salts (electrolytes) when dissolved in certain solvents, especially water, are more or less dissociated into electrically charged ions or parts of the molecules, due to loss or gain of one or more electrons. Loss of electrons results in positive charges producing a cation. A gain of electrons results in the formation of an anion with negative charges. The valence of an ion is equal to the number of charges borne by it.

—J—

Jetting—The process of periodically removing a portion of, or all of, the water, mud and/or solids, from the pits, usually by means of pumping through a jet nozzle arrangement.

Jones Effect—The net surface tension of salt solutions first decreases with an increase of concentration, passes through a minimum, and then increases as the concentration is raised.

—K—

Kelly or Kelly Joint — A heavy square pipe or other configuration that works through a like hole in the rotary table and rotates the drill stem.

Key Seat—That section of a hole, usually of abnormal deviation and relatively soft formation, which has been eroded or worn by drill pipe to a size smaller than the tool joints or collars. This keyhole type configuration will not allow these members to pass when pulling out of the hole.

Killing a Well—Bringing a well under control that is blowing out. Also the procedure of circulating water and mud into a completed well before starting well-service operations.

Kill Line—A line connected to the annulus below the blowout preventers for the purpose of pumping into the annulus while the preventers are closed.

Kinematic Viscosity—The kinematic viscosity of a fluid is the ratio of the viscosity (e.g., cp in g/cm-sec) to the density (e.g., g/cc) using consistent units. In several common commercial viscometers the kinematic viscosity is measured in terms of the time of efflux (in seconds) of a fixed volume of liquid through a standard capillary tube or orifice. See Marsh Funnel Viscosity.

—L—

Laminar Flow—Fluid elements flowing along fixed streamlines which are parallel to the walls of the channel of flow. In laminar flow, the fluid moves in plates or sections with a differential velocity across the front which varies from zero at the wall to a maximum toward the center of flow. Laminar flow is the first stage of flow in a Newtonian fluid; it is the second stage in a Bingham plastic fluid. This type of motion is also called parallel, streamline, or viscous flow. See Plug and Turbulent Flow.

Leonardite—A naturally occurring oxidized lignite. See Lignins.

Lignins, Mined or Humic Acids—Mined lignins are naturally occurring special lignite, e.g., leonardite, that are produced by strip mining from special lignite deposits. The active ingredient is the humic acids. Mined lignins are used primarily as thinners, which may or may not be chemically modified. However, they are also widely used as emulsifiers.

Lignosulfonates — Organic drilling-fluid additives derived from by-products of sulfite paper manufacturing process from coniferous woods. Some of the common salts, such as the ferrochrome, chrome, calcium, and sodium, are used as universal dispersants while others are used selectively for calcium-treated systems. In large quantities, the ferrochrome and chrome salts are used for fluid-loss control and shale inhibition.

Lime—Commercial form of calcium hydroxide.

Lime-treated Muds — Commonly referred to as "lime-base" muds. These high-pH systems contain most of the conventional fresh-water additives to which slaked lime has been added to impart special properties. The alkalinities and lime contents vary from low to high.

Limestone—See Calcium Carbonate.

Lipophile—A substance usually colloidal and easily wetted by oil.

Lipophilic—Having an affinity for oil.

Live Oil—Crude oil that contains gas and has not been stabilized or weathered. This oil can cause gas cutting when added to mud and is a potential fire hazard.

Logging—See Mud Logging and Electric Logging.

Loss of Circulation—See Circulation, Loss of.

Loss of Head or Friction Loss—See Pressure-drop Loss.

Lost-circulation Additives—Materials added to the mud to control or prevent lost circulation. These materials are added in varying amounts and are classified as fiber, flake, or granular.

Lost Returns—See Circulation, Loss of.

Low-solids Muds—A designation given to any type of mud where high performing additives, e.g., CMC, have been partially or wholly substituted for commercial or natural clays. For comparable viscosity and densities (weighted with barite), a low-solids mud will have a lower volume-percent solids content.

Low-yield Clays—Commercial clays chiefly of the calcium montmorillonite type having a yield of approximately 15 to 30 bbl/ton.

Lyophilic—Having an affinity for the suspending medium, such as bentonite in water.

Lyophilic Colloid—A colloid that is not easily precipitated from a solution and is readily dispersible after precipitation by an addition of the solvent.

Lyophobic Colloid—A colloid that is readily precipitated from a solution and cannot be redispersed by an addition of the solution.

—M—

Marsh Funnel—An instrument used in determining the Marsh funnel viscosity. The Marsh funnel is a container with a fixed orifice at the bottom so that when filled with 1,500 cc fresh water, 1 qt (946 ml) will flow out in 26 ± 0.5 sec. For 1,000 cc out, the efflux time for water is 27.5 ± 0.5 sec. See *API RP 13B* for specifications.

Marsh Funnel Viscosity — Commonly called the funnel viscosity. The Marsh funnel viscosity is reported as the number of seconds required for a given fluid to flow 1 qt through the Marsh funnel. In some areas, the efflux quantity is 1,000 cc. See *API RP 13B* for instructions. See also Kinematic Viscosity.

Meniscus—The curved upper surface of a liquid column, concave when the containing walls are wetted by the liquid and convex when not.

Mesh—A measure of fineness of a woven material, screen, or sieve; e.g., a 200-mesh sieve has 200 openings per linear inch. A 200-mesh screen with a wire diameter of 0.0021 in. (0.0533 mm) has an opening of 0.074 mm, or will pass a particle of 74 microns. See Micron.

M_f—The methyl orange alkalinity of the filtrate, reported as the number of milliliters of 0.02 Normal (N/50) acid required per milliliter of filtrate to reach the methyl orange end point (pH 4.3).

Mica—A naturally occurring flake material of varying size used in combatting lost circulation. Chemically, an alkali aluminum silicate.

Micelles—Organic and inorganic molecular aggregates occurring in colloidal solutions. Long chains of individual structural units chemically joined to one another and laid side by side to form bundles. When bentonite hydrates, certain sodium or other metallic ions go into solution, the clay particle plus its atmosphere of ions is technically known as a micelle.

Micron μ = Mu—A unit of length equal to one millionth part of a meter, or one thousandth part of a millimeter.

Milk Emulsion—See Oil-emulsion Water.

Millidarcy—1/1000 darcy. See Darcy.

Mist Drilling—A method of rotary drilling whereby water and/or oil is dispersed in air and/or gas as the drilling fluid.

Ml or Milliliter — A metric system unit for the measure of volume. Literally 1/1000th of a liter. In drilling-mud analysis work, this term is used interchangeably with cubic centimeter (cc). One quart is about equal to 946 ml.

Molecular Weight—The sum of the atomic weights of all the constituent atoms in the molecule of an element or compound.

Molecule—When atoms combine they form a molecule. In the case of an element or a compound, a molecule is the smallest unit which chemically still retains the properties of the substance in mass.

Montmorillonite—A clay mineral commonly used as an additive to drilling muds. Sodium montmorillonite is the main constituent in bentonite. The structure of montmorillonite is characterized by a form which consists of a thin platey-type sheet with the width and breadth indefinite, and thickness that of the molecule. The unit thickness of the molecule consists of three layers. Attached to the surface are ions that are replaceable. Calcium montmorillonite is the main constituent in low-yield clays.

Mud—A water- or oil-base drilling fluid whose properties have been altered by solids, commercial and/or native, dissolved and/or suspended. Used for circulating out cuttings and many other functions while drilling a well. Mud is the term most commonly given to drilling fluids (which see).

Mud Additive — Any material added to a drilling fluid to achieve a particular purpose.

Mudding Off — Commonly thought of as reduced productivity caused by the penetrating, sealing, or plastering effect of a drilling fluid.

Mudding Up—Process of mixing mud additives to achieve some desired purpose not possible with the former fluid, which usually has been water, air, or gas.

Mud House—A structure at the rig to store and shelter sacked materials used in drilling fluids.

Mud Logging—A method of determining the presence or absence of oil or gas in the various formations penetrated by the drill bit. The drilling fluid and the cuttings are continuously tested on their return to the surface, and the results of these tests are correlated with the depth or origin.

Mud-mixing Devices—The most common device for adding solids to the mud is by means of the jet hopper. Some other devices for mixing are: eductors, paddle mixers, electric stirrers, mud guns, chemical barrels, etc.

Mud Pit—Earthen or steel storage facilities for the surface mud system. Mud pits which vary in volume and number are of two types: circulating and reserve. Mud testing and conditioning is normally done in the circulating pit system.

Mud Program—A proposed or followed plan or procedure for the type(s) and properties of drilling fluid(s) used in drilling a well with respect to depth. Some factors that influence the mud program are the casing program and such formation characteristics as type, competence, solubility, temperature, pressure, etc.

Mud Pumps — Pumps at the rig used to circulate drilling fluids.

Mud Scales—See Balance, Mud.

Mud Still—An instrument used to distill oil, water, and other volatile material in a mud to determine oil, water, and total solids contents in volume-percent.

—N—

Natural Clays—Natural clays, as opposed to commercial clays, are clays that are encountered when drilling various formations. The yield of these clays varies greatly, and they may or may not be purposely incorporated into the mud system.

Neat Cement—A slurry composed of portland cement and water.

Neutralization—A reaction in which the hydrogen ion of an acid and the hydroxyl ion of a base unite to form water, the other ionic product being a salt.

Newtonian Flow—See Newtonian Fluid.

Newtonian Fluid — The basic and simplest fluids from the standpoint of viscosity consideration in which the shear force is directly proportional to the shear rate. These fluids will immediately begin to move when a pressure or force in excess of zero is applied. Examples of Newtonian fluids are water, diesel oil, and glycerine. The yield point as determined by direct-indicating viscometer is zero.

Non-conductive Mud—Any drilling fluid, usually oil-base or invert-emulsion muds, whose continuous phase does not conduct electricity, e.g., oil. The spontaneous potential (SP) and normal resistivity cannot be logged, although such other logs as the induction, acoustic velocity, etc., can be run.

Normal Solution—A solution of such a concentration that it contains 1 gram-equivalent of a substance per liter of solution.

—O—

Oil-base Mud—The term "oil-base mud" is applied to a special type drilling fluid where oil is the continuous phase and water the dispersed phase. Oil-base mud contains blown asphalt and usually 1 to 5 percent water emulsified into the system with caustic soda or quick lime and an organic acid. Silicate, salt, and phosphate may also be present. Oil-base muds are differentiated from invert-emulsion muds (both water-in-oil emulsions) by the amounts of water used, method of controlling viscosity and thixotropic properties, wall-building materials, and fluid loss.

Oil Content—The oil content of any drilling fluid is the amount of oil in volume-percent.

Oil-emulsion Water (Milk Emulsion)—A drilling fluid in which the oil content is usually kept between 3 to 7 percent and seldom over 10 percent (it can be considerably higher). The oil is emulsified into fresh or salt water with a chemical emulsifier. Sometimes CMC, starch, or gum may be added to the fresh- and salt-water systems.

Oil-in-water Emulsion Mud — Commonly called "emulsion mud". Any conventional or special water-base mud to which oil has been added. The oil becomes the dispersed phase and may be emulsified into the mud either mechanically or chemically.

—P—

Packer Fluid—Any fluid placed in the annulus between the tubing and casing above a packer. Along with other functions, the hydrostatic pressure of the packer fluid is utilized to reduce the pressure differentials between the formation and the inside of the casing and across the packer itself.

Particle—A minute unit of matter, usually a single crystal, or of regular shape with a specific gravity approximating that of a single crystal.

Parts Per Million—See Ppm.

Parallel Flow—See Laminar Flow.

Pay Zone or Pay Formation—The formation drilled into that contains oil and/or gas in commercial quantities.

Penetration, Rate of—The rate in feet per hour at which the drill proceeds to deepen the well bore.

Peptization—An increased dispersion due to the addition of electrolytes or other chemical substances. See Deflocculation and Dispersion.

Preservative—Usually paraformaldehyde. Any material used to prevent starch or any other substance from fermenting through bacterial action.

Pressure-drop Loss—The pressure lost in a pipeline or annulus due to the velocity of the liquid in the pipeline, the properties of the fluid, the condition of the pipe wall, and the alignment of the pipe. In certain mud-mixing systems, the loss of head can be substantial.

Pressure Surge—A sudden, usually short-duration increase in pressure. When pipe or casing is run into a hole too rapidly, an increase in the hydrostatic pressure results, which may be great enough to create lost circulation.

Pseudoplastic Fluid — A complex non-Newtonian fluid that does not possess thixotropy. A pressure or force in excess of zero will start fluid flow. The apparent viscosity or consistency decreases instantaneously with increasing rate of shear until at a given point the viscosity becomes constant. The yield point as determined by direct-indicating viscometer is positive, the same as in Bingham plastic fluids; however, the true yield point is zero. An example of a pseudoplastic fluid is guar gum in fresh or salt water.

—Q—

Quebracho — A drilling-fluid additive used extensively for thinning or dispersing to control viscosity and thixotropy. It is a crystalline extract of the quebracho tree consisting essentially of tannic acid.

Quicklime—Calcium oxide, CaO. Used in certain oil-base muds to neutralize the organic acid.

Quiescence — The state of being quiet or at rest (being still). Static.

—R—

Radical—Two or more atoms behaving as a single chemical unit, i.e., as an atom; e.g., sulfate, phosphate, nitrate.

Rate of Shear—The rate at which an action, resulting from applied forces, causes or tends to cause two adjacent parts of a body to slide relatively to each other in a direction parallel to their plane of contact. Commonly given in rpm.

Red Mud—A clay, water-base drilling fluid containing sufficient amounts of caustic soda and tannates to give a pronounced red appearance. Normally a high-pH mud.

Red-lime Mud—A red mud which has been converted to a lime-treated mud. The pH is usually 12.0 to 13.0.

Resin—Semisolid or solid complex, amorphous mixture of organic compounds having no definite melting point nor tendency to crystalize. Resins may be a component of compounded materials that can be added to drilling fluids to impart special properties to the system, wall cake, etc.

Resistivity—The electrical resistance offered to the passage of a current, expressed in ohm-meters; the reciprocal of conductivity. Fresh-water muds are usually characterized by high resistivity, salt-water muds by a low resistivity.

Resistivity Meter — An instrument for measuring the resistivity of drilling fluids and their cakes.

Reverse Circulate—The method by which the normal flow of a drilling fluid is reversed by circulating down the annulus and up and out the drill string

Reynolds Number — A dimensionless number, *Re*, that occurs in the theory of fluid dynamics. The diameter, velocity, density and viscosity (consistent units) for a fluid flowing through a cylindrical conductor are related as follows:

$$Re = (diameter)(velocity)(density)/(viscosity)$$

or

$$= DV\rho/\mu.$$

The number is important in fluid hydraulics calculations for determining the type of fluid flow, i.e., whether laminar or turbulent. The transitional range occurs approximately from 2,000 to 3,000; below 2,000 the flow is laminar, above 3,000 the flow is turbulent.

Rheology—The science that deals with deformation and flow of water.

Rotary Drilling—The method of drilling wells that depends on the rotation of a column of drill pipe to the bottom of which is attached a bit. A fluid is circulated to remove the cuttings.

—S—

Salt—In mud terminology, the term salt is applied to sodium chloride, NaCl. Chemically, the term salt is also applied to any one of a class of similar compounds formed when the acid hydrogen of an acid is partly or wholly replaced by a metal or a metallic radical. Salts are formed by the action of acids on metals, or oxides and hydroxides, directly with ammonia, and in other ways.

Salt-water Clay—See Attapulgite Clay.

Salt-water Muds—A drilling fluid containing dissolved salt (brackish to saturated). These fluids may also include native solids, oil, and/or such commercial additives as clays, starch, etc.

Sample Mud—A drilling fluid possessing properties to bring up suitable samples.

Samples—Cuttings obtained for geological information from the drilling fluid as it emerges from the hole. They are washed, dried, and labeled as to the depth.

Sand—A loose granular material resulting from the disintegration of rocks, most often silica.

Sand Content—The sand content of a drilling fluid is the insoluble abrasive solids content rejected by a 200-mesh screen. It is usually expressed as the percentage bulk volume of sand in a drilling fluid. This test is an elementary type in that the retained solids are not necessarily silica nor may not be altogether abrasive. For additional information concerning the kinds of solids retained on the 200-mesh screen, more specific tests would be required. See Mesh.

Saturated Solution—A solution is saturated if it contains at a given temperature as much of a solute as it can retain. At 68 F it takes 126.5 lb/bbl salt to saturate 1 bbl of fresh water. See Supersaturated.

Screen Analysis — Determination of the relative percentages of substances, e.g., the suspended solids of a drilling fluid, passing through or retained on a sequence of screens of decreasing mesh size. Analysis may be by wet or dry methods. Referred to also as "sieve analysis". See Mesh.

Sealing Agents—Any of many materials added to drilling fluids to restore circulation.

Sea-water Muds—A special class of salt-water muds where sea water is used as the fluid phase.

Seconds API—A unit of viscosity as measured with a Marsh funnel according to API procedure. See *API RP 13B* and Marsh Funnel Viscosity.

Sequestration — The formation of stable calcium, magnesium, iron complex by treating water or mud with certain complex phosphates.

Set Casing—The installation of pipe or casing in a well bore. Usually requires mudding up, reconditioning or at least checking the drilling-fluid properties.

Shale—Fine-grained clay rock with slate-like cleavage, sometimes containing an organic oil-yielding substance.

Shale Shaker — Any of several mechanical devices for removing cuttings and other large solids from the mud. Common examples are vibrating screen, rotating cylindrical screen, etc.

Shear (Shearing Stress) — An action, resulting from applied forces, which causes or tends to cause two contiguous parts of a body to slide relatively to each other in a direction parallel to their plane of contact.

Shearometer — A device used as an alternative method for measuring gel strengths. See *API RP 13B* for specifications and procedure.

Shear Strength—A measure of the shear value of the fluid. The minimum shearing stress that will produce permanent deformation. See Gel Strength.

Side Tracking—See Whipstock.

Sieve Analysis—See Screen Analysis.

Silica Gel—A porous substance consisting of SiO_2. Used on occasion as a dehydrating agent in air or gas drilling where small amount of water is encountered.

Silt — Materials that exhibit little or no swelling whose particle size generally falls between 2 microns and API sand size, or 74 microns (200-mesh). A certain portion of dispersed clays and barite for the most part also fall into this same particle-size range.

Skid — Moving a rig from one location to another, usually on tracks where little dismantling is required.

Slip Velocity—The difference between the annular velocity of the fluid and the rate at which a cutting is removed from the hole.

Sloughing—The partial or complete collapse of the walls of a hole resulting from incompetent, unconsolidated formations, high angle or repose, and wetting along internal bedding planes. See Heaving and Cave-in.

Slug the Pipe—A procedure before pulling the drill pipe whereby a small quantity of heavy mud is pumped into the top section to cause an unbalanced column. As the pipe is pulled, the heavier column in the drill pipe will fall, thus keeping the inside of the drill pipe dry at the surface when the connection is unscrewed.

Soap—The sodium or potassium salt of a high-molecular-weight fatty acid. When containing some metal other than sodium or potassium, they are called "metallic" soaps. Soaps are commonly used in drilling fluids to improve lubrication, emulsification, sample size, defoaming, etc.

Soda Ash—See Sodium Carbonate.

Sodium—One of the alkali metal elements with a valence of 1 and an atomic weight of about 23. Numerous sodium compounds (all of which see) are used as additives to drilling fluids.

Sodium Bicarbonate—$NaHCO_3$. A material used extensively for treating cement contamination and occasionally other calcium contamination in drilling fluids. It is the half-neutralized sodium salt of carbonic acid.

Sodium Bichromate—$Na_2Cr_2O_7$. Also correctly called "sodium dichromate". See Chromate.

Sodium Carbonate—Na_2CO_3. A material used extensively for treating out various types of calcium contamination. It is commonly called "soda ash". When sodium carbonate is added to a fluid, it increases the pH of the fluid by hydrolysis. Sodium carbonate can be added to salt (NaCl) water to increase the density of the fluid phase.

Sodium Carboxymethylcellulose—Commonly called CMC. Available in various viscosity grades and purity. An organic material used to control filtration, suspend weighting material, and build viscosity in drilling fluids. Used in conjunction with bentonite where low-solids muds are desired.

Sodium Chloride—NaCl. Commonly known as salt. Salt may be present in the mud as a contaminant or may be added for any of several reasons. See Salt.

Sodium Chromate—Na_2CrO_4. See Chromate.

Sodium Hydroxide—NaOH. Commonly referred to as "caustic" or "caustic soda". A chemical used primarily to impart a higher pH.

Sodium Polyacrylate—A synthetic high-molecular-weight polymer of acrylonitrile used primarily as a fluid-loss-control agent.

Sodium Silicate Muds—Special class of inhibited chemical muds using as their bases sodium silicate, salt, water, and clay.

Solids Concentration or Content — The total amount of solids in a drilling fluid as determined by distillation includes both the dissolved and the suspended or undissolved solids. The suspended-solids content may be a combination of high and low specific gravity solids and native or commercial solids. Examples of dissolved solids are the soluble salts of sodium, calcium, and magnesium. Suspended solids make up the wall cake; dissolved solids remain in the filtrate. The total suspended and dissolved solids contents are commonly expressed as percent by volume, and less commonly as percent by weight.

Sol—A general term for colloidal dispersions, as distinguished from true solutions.

Solubility—The degree to which a substance will dissolve in a particular solvent.

Solute—A substance which is dissolved in another (the solvent).

Solution—A mixture of two or more components that form a homogeneous single phase. Example solutions are solids dissolved in liquid, liquid in liquid, gas in liquid.

Solvent—Liquid used to dissolve a substance (the solute).

Souring—A term commonly used to mean fermentation (which see).

Specific Gravity—See Gravity, Specific.

Specific Heat—The number of calories required to raise 1 g of a substance 1 deg Centigrade. The specific heat of a drilling fluid gives an indication of the fluid's ability to keep the bit cool for a given circulation rate.

Spudding In—The starting of the drilling operations of a new hole.

Spud Mud—The fluid used when drilling starts at the surface, often a thick bentonite-lime slurry.

Spurt Loss—See Surge Loss.

Squeeze—A procedure whereby slurries of cement, mud, gunk plug, etc. are forced into the formation by pumping into the hole while maintaining a back pressure, usually by closing the rams.

Stability Meter—An instrument to measure the breakdown voltage of invert emulsions.

Stacking a Rig—Storing a drilling rig upon completion of a job when the rig is to be withdrawn from operation for a period of time.

Starch—A group of carbohydrates occurring in many plant cells. Starch is specially processed (pregelatinized) for use in muds to reduce filtration rate and occasionally to increase the viscosity. Without proper protection, starch can ferment.

Static—Opposite of dynamic. See Quiescence.

Streaming Potential—The electrokinetic portion of the SP (spontaneous potential) electric-log curve which can be significantly influenced by the characteristics of the filtrate and mud cake of the drilling fluid that was used to drill the well.

Streamline Flow—See Laminar Flow.

Stearate—Salt of stearic acid, which is a saturated, 18-carbon fatty acid. Certain compounds, such as aluminum stearate, calcium stearate, zinc stearate, have been used in drilling fluids for one or more of the following purposes: defoamer, lubrication, air drilling in which a small amount of water is encountered, etc.

Stuck—A condition whereby the drill pipe, casing, or other devices inadvertently become lodged in the hole. May occur while drilling is in progress, while casing is being run in the hole, or while the drill pipe is being hoisted. Frequently a fishing job results.

Supersaturation—If a solution contains a higher concentration of a solute in a solvent that would normally correspond to its solubility at a given temperature, this constitutes supersaturation. This is an unstable condition, as the excess solute separates when the solution is seeded by introducing a crystal of the solute. The term "supersaturation" is frequently used erroneously for hot salt muds.

Surface-active Materials—See Surfactant.

Surfactant—A material which tends to concentrate at an interface. Used in drilling fluids to control the degree of emulsification, aggregation, dispersion, interfacial tension, foaming, defoaming, wetting, etc.

Surfactant Mud—A drilling fluid which contains a surfactant. Usually refers to a drilling fluid containing surfactant material to effect control over degree of aggregation and dispersion or emulsification.

Surface Tension—Generally, the force acting within the interface between a liquid and its own vapor which tends to maintain the area of the surface at a minimum and is expressed in dynes per centimeter. Since the surface tension of a liquid is approximately equal to the interfacial tension between the liquid and air, it is common practice to refer to values measured against air as surface tension, and to use the term "interfacial tension" for measurements at an interface between two liquids, or a liquid and a solid.

Surge Loss—The flux of fluids and solids which occurs in the initial stages of any filtration before pore openings are bridged and a filter cake is formed. Also called "spurt loss".

Suspensoid—A mixture consisting of finely divided colloidal particles floating in a liquid. The particles are so small that they do not settle but are kept in motion by the moving molecules of the liquid (Brownian movement).

Swabbing—When pipe is withdrawn from the hole in a viscous mud or if the bit is balled, a suction is created.

Swelling—See Hydration.

Synergism, Synergistic Properties—Term describing an effect obtained when two or more products are used simultaneously to obtain a certain result. Rather than the results of each product being additive to the other, the result is a multiple of the effects.

—T—

Tannic Acid—Tannic acid is the active ingredient of quebracho and other quebracho substitutes such as mangrove bark, chestnut extract, hemlock, etc.

Temperature Survey—An operation to determine temperatures at various depths in the hole. This survey is used to find the location of inflows of water into the hole, where doubt exists as to proper cementing of the casing and for other reasons.

Ten-minute Gel—See Gel Strength, 10-min.

Thermal Decomposition—The chemical breakdown of a compound or substance by temperature into simple substances or into its constituent elements. Starch thermally decomposes in drilling fluids as the temperature approaches 300 F.

Thinner—Any of various organic agents (tannins, lignins, lignosulfonates, etc.) and inorganic agents (pyrophosphates, tetraphosphates, etc.) that are added to a drilling fluid to reduce the viscosity and/or thixotropic properties.

Thixotropy — The ability of fluid to develop gel strength with time. That property of a fluid which causes it to build up a rigid or semirigid gel structure if allowed to stand at rest, yet can be returned to a fluid state by mechanical agitation. This change is reversible.

Tighten up Emulsion or Mud—Drilling-fluid jargon to describe condition in some systems to which oil has been added and the oil breaks out and rises to the surface. Any chemical or mechanical means which will emulsify the free oil is known as "tightening up".

Titration — A method, or the process of using a standard solution for the determination of the amount of some substance in another solution. The known solution is usually added in a definite quantity to the unknown until a reaction is complete.

Tool Joint—A drill-pipe coupler consisting of a pin and box of various designs and sizes. The internal design of tool joints has an important effect on mud hydrology.

Torque—A measure of the force or effort applied to a shaft causing it to rotate. On a rotary rig this applies especially to the rotation of the drill stem in its action against the bore of the hole. Torque reduction can usually be accomplished by the addition of various drilling-fluid additives.

Total Depth (**or** TD)—The greatest depth reached by the drill bit.

Total Hardness—See Hardness of Water.

Tour—A person's turn in an orderly schedule. The word, which designates the shift of a drilling crew, is pronounced as if it were spelled t-o-w-e-r.

Turbulent Flow—Fluid flow in which the velocity at a given point changes constantly in magnitude and the direction of flow; pursues erratic and continually varying courses. Turbulent flow is the second and final stage of flow in a Newtonian fluid; it is the third and final stage in a Bingham plastic fluid. See Critical Velocity and Reynolds Number.

Twist-off—The severing in two of a joint of drill pipe by excessive force applied by the rotary table.

—U—

Ultraviolet Light—Light waves shorter than the visible blue-violet waves of the spectrum. Crude oil, colored distillates, residuum, a few drilling-fluid additives, and certain minerals and chemicals fluoresce in the presence of ultraviolet light. These substances, when present in mud, may cause the mud to fluoresce.

Univalent—Monovalent. See Valence.

—V—

Valence or Valency—The valence is a number representing the combining power of an atom, i.e., the number of electrons lost, gained, or shared by an atom in a compound. It is also a measure of the number of hydrogen atoms with which an atom will combine or replace, e.g., an oxygen atom combines with two hydrogens, hence has a valence of 2. Thus, there are mono-, tri-, etc. valent ions.

Valence Effect—In general, the higher the valence of an ion, the greater the loss of stability to emulsions, colloidal suspensions, etc. these polyvalent ions will impart.

Velocity—Time rate of motion in a given direction and sense. It is a measure of the fluid flow and may be expressed in terms of linear velocity, mass velocity, volumetric velocity, etc. Velocity is one of the factors which contribute to the carrying capacity of a drilling fluid.

Velocity, Critical—That velocity at the transitional point between laminar and turbulent types of fluid flow. This point occurs in the transitional range of Reynolds numbers of approximately 2,000 to 3,000.

V-G Meter or Viscosity-gravity Viscometer—The name commonly used for the direct-indicating viscometer (which see).

Vibrating Screen—See Shale Shaker.

Viscometer (**Viscosimeter**)—An apparatus to determine the viscosity of a fluid or suspension. Viscometers vary considerably in design and methods of testing.

Viscometer, Direct-indicating—Commonly called a "V-G meter". The instrument is a rotational-type device powered by means of an electric motor or handcrank, and is used to determine the apparent viscosity, plastic viscosity, yield point, and gel strengths (all of which see) of drilling fluids. The usual speeds are 600 and 300 rpm. See *API RP 13B* for operational procedures.

Viscometer, Stormer—A rotational shear viscometer used for measuring the viscosity and gel strength of drilling fluids. This instrument has been largely superseded by the direct-indicating viscometer (which see).

Viscosimeter—See Viscometer.

Viscosity—The internal resistance offered by a fluid to flow. This phenomenon is attributable to the attractions between molecules of a liquid, and is a measure of the combined effects of adhesion and cohesion to the effects of suspended particles, and to the liquid environment. The greater this resistance, the greater the viscosity. See Apparent and Plastic Viscosity.

Viscosity, Funnel—See Funnel Viscosity.

Viscous Flow—See Laminar Flow.

Volatile Matter—Normally gaseous products, except moisture, given off by a substance, such as gas breaking out of live crude oil that has been added to a mud. In distillation of drilling fluids, the volatile matter is the water, oil, gas, etc., that are vaporized, leaving behind the total solids which can consist of both dissolved and suspended solids.

—W—

Wall Cake—The solid material deposited along the wall of the hole resulting from filtration of the fluid part of the mud into the formation.

Wall Sticking—See Differential-pressure Sticking.

Water-base Mud — Common conventional drilling fluids. Water is the suspending medium for solids and is the continuous phase, whether or not oil is present.

Water Block—Reduction of the permeability of a formation caused by the invasion of water into the pores (capillaries). The decrease in permeability can be caused by swelling of clays, thereby shutting off the pores, or in some cases by a capillary block of the pores due to surface tension phenomena.

Water-in-oil Emulsion — See Invert Oil-emulsion Mud.

Water Loss—See Fluid Loss.

Weight—In mud terminology, this refers to the density of a drilling fluid. This is normally expressed in either lb/gal, lb/cu ft, psi hydrostatic pressure per 1,000 ft of depth.

Weight Material—Any of the high specific gravity materials used to increase the density of drilling fluids. This material is most commonly barite but can be galena, etc. In special applications limestone is also called a weight material.

Well Logging—See Electric Logging and Mud Logging.

Wetting—The adhesion of a liquid to the surface of a solid.

Wetting Agent—A substance or composition which, when added to a liquid, increases the spreading of the liquid on a surface or the penetration of the liquid into a material.

Whipstock—A device inserted in a well bore used for deflecting or for directional drilling.

Wildcat—A well in unproved territory.

Workover Fluid—Any type of fluid used in the workover operation of a well.

—Y—

Yield—A term used to define the quality of a clay by describing the number of barrels of a given centipoise slurry that can be made from a ton of the clay. Based on the yield, clays are classified as bentonite, high-yield, low-yield, etc., types of clays. Not related to yield value below. See *API RP 13B* for procedures.

Yield Point — In drilling-fluid terminology, yield point means yield value (which see). Of the two terms, yield point is by far the most commonly used expression.

Yield Value — The yield value (commonly called "yield point") is the resistance to initial flow, or represents the stress required to start fluid movement. This resistance is due to electrical charges located on or near the surfaces of the particles. The values of the yield point and thixotropy, respectively, are measurements of the same fluid properties under dynamic and static states. The Bingham yield value, reported in lb/100 sq ft, is determined by the direct-indicating viscometer by subtracting the plastic viscosity from the 300-rpm reading.

—Z—

Zero-zero Gel — A condition wherein the drilling fluid fails to form measurable gels during a quiescent time interval (usually 10 min).

Zeta Potential—Electrokinetic potential of a particle as determined by its electrophoretic mobility. This electric potential causes colloidal particles to repel each other and stay in suspension.

Zinc Chloride—$ZnCl_2$. A very soluble salt used to increase the density of water to points more than double that of water. Normally added to a system first saturated with calcium chloride.

Appendix 4.4

API BUL 10C
Second Edition
April 1969

API
BULLETIN
on
OIL-WELL CEMENT NOMENCLATURE

OFFICIAL PUBLICATION

REG. U.S. PATENT OFFICE

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Foreword

a. This bulletin is under the jurisdiction of the API Committee on Standardization of Oil-Well Cements.

b. The purpose of this bulletin is to provide definitions for the most commonly used terms associated with oil-well cementing.

c. Metric conversions of U. S. customary units* are provided throughout the text of this bulletin in parentheses, e.g., 6,000-ft (1830 m). The values stated in U. S. customary units are to be regarded as the standard. The metric equivalents of U. S. customary units given in the body of the bulletin and in the appendix (if any) may be approximate. Note the use of period instead of comma for decimal point in metric values, e.g., 209.6 mm instead of 209,6 mm. The factors used for conversion of U. S. customary units to metric values are:

1 cubic foot (cu ft)	= 0.0283 cubic meter (m^3)
1 cubic foot per minute (cu ft/min)	= 0.4720 liter per second (l/sec)
1 inch (in.)	= 25.4 millimeters (mm) exactly
1 foot (ft)	= 0.3048 meter (m) exactly
1 pound (lb)	= 0.454 kilogram (kg)
1 pound per foot (lb/ft)	= 1.4895 kilograms per meter (kg/m)
1 pound per gallon (lb/gal)	= 0.1198 kilogram per liter (kg/l)
1 pound per square inch (psi)	= 0.0703 kilogram per square centimeter (kg/cm^2)

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*U. S. Customary Units — Units based upon the yard and the pound commonly used in the United States of America and defined by the National Bureau of Standards. Some of these units have the same name as similar units in the United Kingdom (British, English, or U.K. Units) but are not necessarily equal to them.

d. Related publications under jurisdiction of the API Committee on Standardization of Oil-Well Cements are:

Std 10A: Specification for Oil-Well Cements and Cement Additives.

Covers chemical and physical requirements, sampling, test methods, packaging, storage, and marking requirements for various classes of oil-well cements.

RP 10B: Recommended Practice for Testing Oil-Well Cements and Cement Additives.

Covers test procedures, methods, and equipment used to evaluate and define those physical properties of cements of special importance to the oil and gas industry.

Bul D4: The Effects of Drilling Mud Additives on Oil-Well Cements.

Contains tables and charts summarizing data obtained from cooperative tests conducted by the API Mid-Continent District Study Committee on Cementing Practices and Testing of Oil-well Cements to determine the effect of drilling-mud treating chemicals on thickening time and strength of API Class A, D, and E oil-well cement.

NOTE: *This edition supersedes the first edition, dated March 1963. It includes revisions adopted at the 1968 midyear meeting and subsequently approved by letter ballot as detailed in Circ PS-1363.*

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API BULLETIN ON
OIL-WELL CEMENT NOMENCLATURE

Absolute Volume. The volume per unit mass, reciprocal of absolute density.

Accelerator. A material which accelerates or speeds up the normal rate of reaction between cement and water, resulting in an increase in the development of early strength, and, in some cases, a decrease in the setting time or thickening time.

Acid Resistance. The ability of a hardened cement slurry to withstand the softening and corrosive effects of organic or mineral acids, or water solutions of these acids and their salts having a pH lower than 7.0.

Additive. A material other than cement and water which is added to a cement subsequent to its manufacture to modify its properties.

Admix. To add one material to another by mixing.

NOTE: *Admix should not be used replaceably with additive.*

Aging. Natural or artificial maturing of cement, cement slurries, and hardened cement paste during which various physico-chemical changes take place.

Aggregate. An essentially inert material of mineral origin having a particle size predominantly greater than 100 mesh, which forms a mortar or concrete when bound together with hardened cement paste.

Annulus, Annular Space. Any space in a well bounded by two or more circular surfaces, one of which is concave. This would include single or multiple strings of tubing in a hole or casing.

API Cement Classes. A classification system for oil well cements defined in API Std 10A.

Asphaltic Material. One of a group of solid, liquid, or semi-solid materials, predominantly mixtures of hydrocarbons and their non-metallic derivatives, obtained either from natural bituminous deposits, or from the residue of petroleum refining.

Autoclave Expansion. A measurement or test made as provided in ASTM C 151: *Test for Autoclave Expansion of Portland Cement.* See Soundness.

Barite. A native crystalline barium sulfate, which occurs in snow-white crystalline masses, or grayish, reddish, and greenish ores with a specific gravity of 4 to 4.6. It is used for increasing the density of oil well cement slurries and drilling fluids. See API Std 10A. Synonym — Barytes, heavy spar.

Barrel of Cement. A dry weight measure of cement equal to 4 cu ft (0.11 m^3) or 376 lb (171 kg).

Barrel of Cement Slurry. 42 gallons (6.7 m^3) of cement slurry.

Bentonite. A highly plastic, highly colloidal clay, largely made up of the mineral, montmorillonite.

Bleeding. Separation of the liquid phase in a cement slurry.

Bond. Adhering, binding, or joining of two materials; e.g., cement to casing.

Bonding. The state of bond between cement and casing and/or formation.

Bridging Material. Fibrous, flaky, or granular material added to a cement slurry or drilling fluid to aid in sealing formations in which lost circulation has occurred. See Lost Circulation Material.

Casing Cementing. The practice of filling the annulus between casing and hole with cement in order to prevent fluid migration between permeable zones and to support the casing.

Cement. (a) n.; A plastic material which hardens and forms a firm connecting medium between two or more solids. (b) v.t.; The act of placing cement.

Additive Cement. A cement or cement slurry to which an additive has been blended.

ASTM Type Cement. A portland cement meeting the requirements of ASTM C 150: *Standard Specifications for Portland Cement.*

Common Cement. (a) API Class A cement; (b) ASTM Type I cement.

Construction Cement. Normally, an ASTM Type I, II, or III portland cement (ASTM C 150: *Standard Specifications for Portland Cement*) and air-entraining modifications (ASTM C 175: *Air Entraining Portland Cement*). API Class A, B, and C are similar to ASTM Type I, II, and III, respectively. Air-entraining cements are not suitable for oil well cementing.

Gel Cement. A cement or cement slurry that has been modified by the addition of bentonite.

High Early Cement. (a) API Class C cement; (b) ASTM Type III cement.

High Temperature Cement. A cement composition designed to overcome strength retrogression.

Hydraulic Cement. A cement that hardens or sets under water.

Modified Cement. A cement whose properties, chemical or physical, have been altered by additives. This term has been used to refer to specific formulations of gel cement containing certain concentrations of dispersing agent.

Neat Cement. A cement or cement slurry containing no additives.

Oil-Well Cement. Cement or any mixture of cement with other materials that is intended for use in oil, gas, or water wells.

Portland Cement. The product obtained by grinding clinker consisting essentially of hydraulic calcium silicates, to which no additions have been made subsequent to calcination other than water and untreated calcium sulfate, except that additions not to exceed 1.0% of other materials may be interground with the clinker at the option of the manufacturer, provided such materials in the amount indicated have been shown to be not harmful by tests carried out or reviewed by ASTM Committee C-1 on cement.

Regular Cement. (a) API Class A cement, (b) ASTM Type I cement. See Common Cement.

Retarded Cement. A cement in which the thickening time is extended by adding a chemical retarder.

Slow-Set Cement. A cement in which the thickening time is extended by (1) eliminating the rapid hydrating components in its composition or (2) by adding a chemical retarder. API Class D, E, and F are slow-set cements.

Sulfate-Resistant Cement. Cements which meet applicable requirements of API Std 10A.

Weighted Cement. A cement slurry containing additives to increase its normal density.

Cement Additive. See Additive.

Cement Density. The specific gravity of an oil well cement as determined by a method similar to ASTM C 188: *Specific Gravity of Hydraulic Cement.* Most portland cements have a specific gravity of about 3.15 when tested by this method. Cement density should not be confused with slurry density.

Cement System. The combination of materials which make up an oil well cement slurry.

Cementing Time. The total elapsed time for a cementing operation from the beginning of mixing until the completion of displacement to final depth and complete circulation of any excess slurry to the surface.

Collodial Suspension. A stable, homogeneous system of very fine particles of matter dispersed uniformly throughout a liquid medium, having properties which differ both from a true solution and from a suspension of larger particles. True collodial suspensions have particle size range of 5 to 200 millimicron.

Compressive Strength. The degree of resistance of a material to force acting along one of the axes in a manner tending to crush it, usually expressed in pounds of force per square inch of surface affected. See API RP 10B.

Consistency. A rheological property of matter which is related to the cohesion of the individual particles of a given material, its ability to deform, and its resistance to flow. The consistency of cement slurries is determined in accordance with API RP 10B. It is expressed as units of consistency (Uc) when determined either on the pressure-temperature thickening-time tester or on the atmospheric pressure consistometer.

Contaminant. Material, usually a mud component, which becomes mixed with the cement slurry during the displacement process, and which has a deleterious effect on cement properties.

Curing. Aging of cement under specified conditions.

Atmospheric Pressure Curing. The aging of cement specimens for test purposes at normal atmospheric pressure of 14.7 psi (1 kg/cm^2) at sea level, for a designated period of time under certain given conditions of temperature and humidity. See API RP 10B.

Pressure Curing. The curing of cement specimens for test purposes, in water at pressures above atmospheric pressure. See API RP 10B.

Decontaminant. Material added to cements or cement slurries for the specific purpose of counteracting the effects of contamination.

Dehydration. Loss of water by filtration of cement slurries during or after displacement.

Density. Mass per unit volume. Absolute density considers only the actual volume occupied by the material. Bulk density is mass per unit bulk volume which includes the actual volume of the material plus the volume of trapped air.

Diatomaceous Earth. A material from siliceous remains of single-celled organisms. Pulverized diatomaceous earth is sometimes used as a cement additive.

Dispersant. A cement additive which reduces the initial consistency of cement slurries.

Displacement Rate. The volumetric flow rate at which cement slurry is pumped down the hole.

Drilling Fluid. Any fluid, such as air or gas, water- or oil-base muds, circulated in a well during drilling operations.

Dry Basis. The weight of an additive corrected for moisture.

Dry Blending. The process of admixing finely-divided solid components.

Emulsion. An intimate mixture of liquids mutually insoluble, one of which is distributed throughout the other in the form of globules.

Expanded Perlite. A siliceous volcanic rock that is ground to small size and subjected to extreme temperature in an oven, resulting in an expansion and release of combined water, leaving the rock particle considerably expanded and porous.

Extrapolated Thickening Time. The time required for a cement slurry to reach a consistency of 100 units of consistency (Uc) obtained by extending the curve recorded during a thickening-time test which may be stopped at 70 Uc under given conditions. See API RP 10B.

False Set. An abnormal early thickening of cement slurry wherein the slurry remains pumpable for the usual thickening time. The thickening may be reversible during the pumping history of the slurry.

Filler Material. A material added to a cement or cement slurry for the primary purpose of increasing the yield of the slurry.

Filter. A porous medium through which fluid is passed to separate it from material held in suspension.

Filter Cake. The solid material deposited on a porous medium resulting from the filtration of the fluid part of a liquid-solid suspension.

Filter Loss. A misnomer sometimes applied to fluid loss.

Filter Press. The apparatus used to obtain fluid loss. See API RP 10B.

Filtrate. The liquid phase of a cement slurry that passes through a filter and deposited filter cake.

Filtration. The process of separating suspended solids from liquids by passing through a filter.

Final Set. Cement shall be considered to have acquired its final set when it will bear, without appreciable indentation, the final Gillmore needle. This is *not* an API test. See ASTM C 266: *Time of Setting of Hydraulic Cement by Gillmore Needles.*

Final Strength. The strength of a cement at such a time when under the given conditions of temperature and pressure it ceases to change significantly. Synonym — Ultimate Strength.

Fineness. The particle size to which a cement clinker is ground. This value is generally reported as surface area as determined with the Blaine air permeability apparatus or Wagner turbidimeter.

Fissure. A natural crack or fracture which occurs in a formation.

Flash Set. Flash set is abnormal early thickening or setting of cement slurry wherein the cement slurry becomes unpumpable.

Fluid Loss. The volume of fluid lost to a permeable material due to the process of filtration. The API fluid loss is the volume of fluid in a filtrate as determined according to the *Fluid-Loss Test* given in API RP 10B. See Water Loss.

Fluid Loss Additive. An additive used to reduce the fluid loss of cement slurries.

Fly Ash. The finely divided residue that results from the combustion of ground or powdered coal and is transported from the firebox through the boiler by flue gases. Fly ash is an artificial pozzolan. See Pozzolan.

Fracture. Crack and crevice in the formation either inherent or induced.

Friction Reducer. See Dispersant. The addition of a dispersant will cause turbulence at a lower velocity. The friction of a cement slurry may be increased, however, if the flow regime is changed.

Gel. (a) Usually refers to sodium bentonite clays belonging to the general class of montmorillonites. (b) The colloidal suspension in such a state that shearing stresses below a certain finite value fail to produce permanent deformation.

Gel Strength. The value of the shear stress required to cause permanent deformation of a coloidal suspension.

Gilsonite. A naturally occurring solid hydrocarbon belonging to the asphalt group. A granular form of gilsonite is sometimes used as a cement additive.

Grouting. The filling of void space with a substance that hardens (grout). It is performed to prevent passage of fluids or gases or to prevent compaction of materials in a formation.

Gunk Squeeze. A bentonite, diesel-oil mixture that is pumped down the drill pipe to mix with drilling mud being pumped down the annulus. These two mix to form a stiff, putty-like material that can be squeezed into lost circulation zones.

Ilmenite. An iron-black mineral of composition $FeO \cdot TiO_2$ having a specific gravity of 4.67. It is used for increasing the density of oil-well cement slurries and drilling fluids.

Initial Set. Cement shall be considered to have acquired its initial set when it will bear, without appreciable indentation, the initial Gillmore needle. This is *not* an API test. See ASTM C 266: *Time of Setting of Hydraulic Cement by Gillmore Needles.*

Laminar Flow. Fluid flow where neighboring layers are not mixed.

Latex. Colloidal suspension or emulsion of organic materials. Certain latexes are sometimes used as cement additives.

Lost Circulation Material. A material added to cement slurries or drilling fluids which is designed to prevent the loss of cement or mud to the formation. See Bridging Material.

Minimum Water. The minimum water content of a cement slurry determined by the procedure given in Section 3 of API RP 10B.

Mud. A colloquial term used to describe drilling fluids.

Optimum Water. The amount of water used in a cement slurry which gives the slurry the best properties for its particular application.

Ordinary Cement. A cement intended for use when conditions do not require moderate to high sulfate-resistance corresponding to API Class A or Class C designations. These cements are similar to ASTM Type I or Type III cement, respectively.

Per Cent Additive. The parts of additive per 100 parts of cement either by volume or by weight. Per cent, usually refers to per cent, by weight. If per cent, by volume is meant, it should be so stated.

Per Cent Water. The water content of a cement slurry expressed as parts of water per 100 parts of dry cement by weight. Per cent, usually refers to per cent, by weight. If per cent, by volume is meant, it should be so stated.

Permeability. The property of a solid medium which allows a fluid to flow through its interconnected pore network. A procedure for determining the permeability of hardened cement is given in API RP 10B.

Plasticity. The property of a substance to be deformed by pressure without being ruptured.

Plug Flow. Fluid moving as a unit in which all of the shear stress occurs close to the wall.

Plugging Material. A material used to block off zones while treating or working on other portions of the well. This blocking off may be temporary or permanent.

Poise. The metric unit for measurement of viscosity. Although the viscosity of cement slurries is expressed in poises for convenience, it is recognized that they do not behave as true Newtonian fluids (see Viscosity).

Portland Cement Clinker. Hard granular nodules composed essentially of hydraulic calcium silicates, with smaller quantities of calcium aluminates and ferrites, produced by the heat treatment of cement raw materials in a kiln. Clinker is pulverized with the proper quantity of calcium sulfate in the manufacture of portland cements.

Pozzolan. A siliceous or siliceous and aluminous material, which in itself possesses little or no cementitious value but will, in finely-divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties. See ASTM C618: *Fly Ash and Raw or Calcined Natural Pozzolans for Use in Portland Cement Concrete.*

Pozzolan-Cement Mixture. A mixture comprising both cement and a pozzolan.

Pozzolanic Reaction. The chemical combination of certain finely divided siliceous or siliceous and aluminous materials with calcium hydroxide or lime, in the presence of moisture, to form compounds which have cementitious properties.

Pressure. Force per unit area.

Bottom Hole Circulating Pressure. The pressure at the bottom of a well during circulation of any fluid. It is equal to the hydrostatic head plus the annular friction loss required to pump the fluid to the surface plus any back pressure held at the surface.

Bottom Hole Static Pressure. The pressure at the bottom of a well after the well is shut-in long enough to reflect ambient formation pressure.

Circulating Pressure. The pressure at a specified depth required to circulate a fluid in a well at a given rate.

Final Squeeze Pressure. The pressure at the completion of a squeeze cementing operation. Final squeeze pressure usually refers to the surface pressure.

Surface Pressure. The pressure measured at the wellhead.

Primary Cementing. Primary casing cementing is the original cementing operation performed immediately after casing has been run into the hole. See Casing Cementing.

Puddling. In cement evaluation work, the term applies to agitation of cement slurry in molds with a rod, to remove any trapped air bubbles. In field practice, the term has been used to denote the reciprocation or rotation of the casing during or after a cementing operation.

Pumpability. A measure of the properties of a fluid or cement slurry to be pumped.

Pumping Time. Synonymous with cementing time except in those instances where a volume of cement slurry is premixed prior to displacement in a well. In this instance, the pumping time will be total cementing time minus mixing time.

Retarder. A chemical which is added to cements to increase their thickening time.

Sack. Sack is a weight measure. Cement, betonite, and barite are marketed in sacks containing amounts as follows:

Cement	94 pounds (42.5 kg)
Bentonite	100 pounds (45.4 kg)
Barite	100 pounds (45.4 kg)

NOTE: *For most operations outside the United States, the normal sack is 50 kg (110 lb) of each material.*

Setting Time. A term defining the hardening time of construction cement. This term is not normally used with reference to oil-well cement.

Settling. Separation of particles because of different sizes and specific gravities.

Silica Flour. Silica (SiO_2), sand, ground to a fineness equal to portland cement. The fineness of portland cement is specified in API Std 10A.

Slurry. Suspension of cement in water, oil, or mixture of both.

Slurry Volume. The sum of the absolute volumes of solids and liquids that constitute a slurry.

Slurry Density. The density of a cement slurry expressed in either pounds per gallon or pounds per cubic foot. Light-weight and heavy-weight slurries are prepared by adding suitable additives to modify slurry density.

Slurry Weight. See Slurry Density.

Slurry Yield. (a) Volume of slurry when one sack of cement (94 pounds, 42.5 kg) is mixed with desired amount of water containing any other additive such as accelerators, fluid-loss control agents, etc. (b) Slurry volume as previously defined divided by the total number of sacks of cement (94 pounds, 42.5 kg per sack).

Squeeze Cementing. The process of forcing cementing material under pressure into a specific portion of a well, such as fractures, openings, or permeable zones.

High Pressure Squeeze Cementing. The forcing of cement slurry into the points to be squeezed with a final pressure equal to or greater than the formation breakdown pressure.

Low Pressure Squeeze Cementing. The forcing of cement slurry into the points to be squeezed with a pressure not exceeding the formation breakdown pressure.

Soundness. A measure of the expansive properties of a cement as determined by the autoclave expansion test given in ASTM C 151: *Test for Autoclave Expansion of Portland Cement.*

Stratification. The natural layering or lamination usually characteristic of sediments and sedimentary rocks. Stratification is the result of the settling of particles of different sizes and specific gravities.

Strength Retrogression. The decline of strength of the hardened cement slurry with age, which may occur at temperatures above 180 F (82 C).

Sulfate Resistance. The ability of a cement to resist deterioration in the presence of sulfate ions.

Surfactant. Any compound that affects (usually reduces) surface tension when dissolved in water or water solutions, or which similary affects interfacial tension between two phases.

Temperature. The degree of heat, usually expressed in either U. S. customary units as degrees Fahrenheit (F) or metric equivalent units as degrees Celsius (C) (formerly called the Centigrade scale).

Bottom Hole Circulating Temperature. The temperature of any fluid at the bottom of the well while it is being circulated.

Bottom Hole Static Temperature. The temperature attained at the bottom of a well after the well is shut-in. See Static Temperature.

Casing Cementing Temperature. The temperature of a cement slurry while it is being displaced at the maximum cementing depth in a casing cementing operation.

Circulating Temperature. The temperature of any fluid at any specified depth in well while it is being circulated, as measured inside casing or drill pipe.

Squeeze Cementing Temperature. The temperature of a cement slurry while it is being displaced at the maximum cementing depth in a squeeze cementing operation.

Static Temperature. The temperature attained at a specified depth in a well after the well is shut-in long enough to reflect the ambient formation temperature.

Temperature Stability. The chemical characteristics of a material which determine its resistance to thermal decomposition.

Tensile Strength. A measure of force per unit cross sectional area required to pull a specimen apart.

Thickening Time. The time required for a cement slurry of a given composition to reach a consistency of 100 units of consistency (Uc), determined by methods outlined in API RP 10B.

Thixotropy. The property exhibited by certain systems of gelling when in a static state, and then liquefying when subjected to agitation.

Turbulence Inducer. See Friction Reducer.

Turbulent Flow. The flow of a fluid in an erratic, non-linear fashion occuring at high velocities.

1000, 10-76, Egan
1500, 10-77, Egan
2000, 4-79, Egan
2000, 2-80, Egan
2600, 2-81, Egan
2000, 6-82, Egan

Unit of Consistency. A standard value of measurement relating torque equivalent to degree of firmness of a cement slurry. See API RP 10B Unit of Consistency (Uc).

Viscosity. The internal resistance of a fluid to flow.

Initial Viscosity. The consistency of a cement slurry determined after a brief shearing time. In some publications this term has reference to the maximum consistency observed between 15 and 30 minutes in a thickening time test.

Slurry Viscosity. The consistency of a slurry measured in units of slurry consistency, Uc.

Vug. Natural cavity formed in certain formations due to leaching out of soluble minerals. These cavities are lined with a crystalline material and a composition different from that of the surroundings. The size of a vug may vary from a small pea to a large boulder.

Water-Cement Ratio. The ratio by weight of water to cement in a cement slurry.

Water Loss. The volume of water lost to the permeable material due to the process of filtration. The API water loss is the volume of filtrate determined according to the *Fluid-Loss Test* given in API RP 10B. See Fluid Loss.

High Water Loss. A cement slurry is arbitrarily considered to exhibit a high water loss when the volume of filtrate determined according to the *Fluid Loss Test* given in API RP 10B exceeds 500 ml.

Low Water Loss. A cement slurry is considered low water loss when the volume of filtrate as determined above is less than 50 ml.

Medium Water Loss. A cement slurry is considered medium water loss when the volume of filtrate as determined above is between 50 and 500 ml.

Water Loss Control. To regulate the water loss of a cement slurry by the use of additives.

Water of Hydration. The water chemically combined with the solid to form a crystalline compound. In cement slurries, the water necessary to hydrate the cement, forming cementitious materials.

Water-Solids Ratio. The ratio by weight of water to the total solids in a cement slurry.

Weighting Material. A material which when added to a cement slurry increases the density of the slurry.

Well Simulation Test. A test performed in accordance with API RP 10B under conditions simulating those encountered in wells.

Yield Point. The shear stress intercept resulting from an extrapolation of higher shear stress-shear rate values to a zero shear rate.

Appendix 4.5

API Spec 10
First Edition
January 1982

API
SPECIFICATION
for
MATERIALS and TESTING
for
WELL CEMENTS

OFFICIAL PUBLICATION

REG. U.S. PATENT OFFICE

AMERICAN PETROLEUM INSTITUTE
Washington. D.C.

Issued by
AMERICAN PETROLEUM INSTITUTE
Production Department
211 N. Ervay, Suite 1700
Dallas TX 75201

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Note: This edition supersedes the twentieth edition of Spec 10A and the twenty-first edition of RP 10B. It includes revisions adopted at the 1981 Standardization Conference and subsequently approved by letter ballot as described in Circ PS 1664.

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Appendix 5 Corporate Linkages

Project No. M1272
DSS File No. -
02GS,23230-5-0004

For each company, the information is in two sets:

The top item from the CLRA data base keys on the name of the company operating in the East Coast offshore. Each is identified as level 2, meaning that it is owned to the indicated extent by the level 1 company above. All subsidiaries of the level 1 company which operate in Canada are listed as level 2, of level 2 companies as level 3, and so on, with percentage ownership indicated.

The second item, from the Dow Jones data base and titled "American Data", provides various details about the parent company including the names of all subsidiaries.

HALLIBURTON

```
====> CLRA  SEARCH 1 - DOCUMENT 1 OF 1 (000059809) 1 PAGE

    CTL    RES    SIC      %      LEVEL / NAME
NAME:
    C=USA R=USA S=000 %=          01 HALLIBURTON COMPANY
SUBS:
    C=USA R=ALT S=099 %=099.98   02 HALLIBURTON SERVICES LTD
    C=USA R=ALT S=502 %=100.00    03 HOWCO AIR LIMITED
    C=USA R=NB  S=315 %=099.94   02 FREIGHTMASTER OF CANADA LTD.
    C=USA R=USA S=000 %=100.00   02 OTIS ENGINEERING CORP.
    C=USA R=ALT S=099 %=100.00    03 OTIS ENGINEERING CO. LTD.
    C=USA R=USA S=000 %=100.00   02 BROWN & ROOT INC.
    C=USA R=ALT S=409 %=100.00    03 BROWN & ROOT LTD
    C=USA R=QUE S=756 %=100.00    03 BROWN & ROOT (QUEBEC) INC
    C=USA R=SAS S=409 %=099.50    03 CANTILEVER CONSTRUCTION LTD
    C=USA R=ALT S=623 %=099.50    03 MARWIN FABRICATORS LTD.


AMERICAN DATA (DOW JONES-SEC)

OWNERSHIP:
TYPE            DATE(Q,M)  OWNERS    CHANGE (000S) HELD   %OWN
INVEST. COS.    06/30/85(Q)                0          0   0.00
INSTITUTIONS    06/30/85(Q)  303       2,526     66,638  61.33
5% OWNERS       07/31/85(M)    0          NA          0   0.00
INSIDERS        06/30/85(M)   12          NA        310   0.28
% OWNED MAY TOTAL ABOVE 100% DUE TO OVERLAPPING HOLDINGS REPORTS

SUBSIDIARIES:
HALLIBURTON INTERNATIONAL, INC.
HALLIBURTON SERVICES LIMITED
HALLIBURTON DE MEXICO, S.A. DE C.V.
COMPANIA HALLIBURTON DE CEMENTACION Y FOMENTO, C.A.
HALLIBURTON ARGENTINA, S.A.
HALLIBURTON COMPANY GERMANY, G.M.B.H.
HALLIBURTON LIMITED
HALLIBURTON MANUFACTURING AND SERVICES LIMITED
JET RESEARCH CENTER, INC.
BROWN & ROOT, INC.
*BROWN & ROOT U.S.A, INC.
*MID-VALLEY, INC.
*ALLIED INDUSTRIES, INC.
*BROWN & ROOT DEVELOPMENT, INC.
*BROWN & ROOT INTERNATIONAL, INC.
**BROWN & ROOT MIDDLE EAST, S.A.
**BROWN & ROOT OFFSHORE, N.V.
**NKK-BROWN & ROOT OVERSEAS, S.A., 50%
**REZAVAT-BROWN & ROOT E.C., 49%
*BROWN & ROOT, LTD.
*BROWN & ROOT (U.K.  LTD.
**BROWN & ROOT CONSTRUCTION LIMITED
**BROWN & ROOT-WIMPEY HIGHLANDS FABRICATORS LIMITED, 50%
```

*BROWN & ROOT (OVERSEAS) LTD.
*DEEPWATER HOLDINGS B.V., 70%
**DEEP MARINE SERVICES B.V., 70%
**DEEP OCEAN SERVICES B.V., 70%
*BROWN & ROOT (NORGE) A/S
*BROWN & ROOT (LABUAN) SENDIRIAN BERHAD
*P.T. BROWN & ROOT INDONESIA
*TECHNICOS-IP&C
*BROWN & ROOT DE MEXICO, S.A. DE C.V. *CORPORACION DE CONSTRUCCIONES DE CAMPECHE, S.A. DE C.V., 49%
NUS CORP., 99% JOE D. HUGHES, INC.
TAYLOR DIVING & SALVAGE CO., INC.
WM. A. SMITH CONSTRUCTION CO., INC.
ALASKA CONSTRUCTORS, INC.
OTIS ENGINEERING CORP.
*OTIS MEXICANA, S.A.
*OTIS ENGINEERING INTERNATIONAL, C.A.
*OTIS ENGINEERING, G.M.B.H.
*OTIS PRESSURE CONTROL, LTD.
*OTIS INTERNATIONAL, LTD. *HOWARD SMITH SCREEN CO.
VERNON GRAPHICS, INC.
HALLIBURTON INTERNATIONAL SALES CO.
HIGHLANDS INSURANCE CO.
HIGHLANDS OVERSEAS LIMITED
HIGHLANDS LIMITED
LIFE INSURANCE CO. OF THE SOUTHWEST

DISCLOSURE CO NO: H070400000
COMPANY NAME: HALLIBURTON CO
CROSS REFERENCE: NA
ADDRESS: 2600 SOUTHLAND CENTER
400 NORTH OLIVE, L. B. 263 DALLAS
TX 75201
TELEPHONE: 214-978-2600
INCORPORATION: DE
EXCHANGE: NYS
TICKER SYMBOL: HAL
FORTUNE NUMBER: S006
CUSIP NUMBER: 0004062162
D-U-N-S NO: 04-329-6920
SIC CODES: 1389 3533 1629 8911
PRIMARY SIC CODE: 1389

DESCRIPTION OF BUSINESS: PROVIDES OIL FIELD SERVICES AND PRODUCTS INDUSTRIAL ENGINEERING/CONSTRUCTION SERVICES MARINE ENGINEERING/CONSTRUCTION SERVICES AND SPECIALTY SERVICES AND PRODUCTS FOR GENERAL INDUSTRY.

CURRENT OUTSTANDING SHARES: 108,693,354 (SOURCE: 10-Q 10/31/85)

SHARES HELD BY OFF & DIR: 372,052 (SOURCE: PROXY)
SHAREHOLDERS: 25,938 (SOURCE: 10-K)
EMPLOYEES: 68,000 (SOURCE: 10-K)
FISCAL YEAR END: 12/31

INCOME STATEMENT

FISCAL YEAR ENDING:	12/31/84	12/31/83	12/31/82
NET SALES	5,427,693,000	5,510,744,000	7,281,793,000
COST OF GOODS	4,720,221,000	4,813,892,000	6,169,454,000
GROSS PROFIT	707,472,000	696,852,000	1,112,339,000
R & D EXPENDITURES	NA	NA	NA
SELL GEN & ADMIN EXP	227,608,000	207,280,000	231,360,000
INC BEF DEP & AMORT	479,864,000	489,572,000	880,979,000
DEPRECIATION & AMORT	NA	NA	NA
NON-OPERATING INC	188,744,000	137,954,000	45,903,000
INTEREST EXPENSE	138,047,000	132,050,000	123,743,000
INCOME BEFORE TAX	530,561,000	495,476,000	803,139,000
PROV FOR INC TAXES	240,004,000	220,446,000	325,333,000
MINORITY INT INCOME	2,547,000	4,079,000	5,445,000
INVEST GAINS/LOSSES	NA	NA	NA
OTHER INCOME	41,585,000	43,887,000	39,287,000
NET INC BEF EX ITEMS	329,595,000	314,838,000	511,648,000
EX ITEMS & DISC OPS	NA	-39,023,000	-14,803,000
NET INCOME	329,595,000	275,815,000	496,845,000
OUTSTANDING SHARES	108,495,723	118,347,408	118,080,337

INCOME STATEMENT

QUARTERLY REPORT FOR:	03/31/85	06/30/85	09/30/85
NET SALES	1,172,213,000	2,399,629,000	1,175,778,000
COST OF GOODS	1,033,036,000	2,380,204,000	1,051,970,000
GROSS PROFIT	139,177,000	19,425,000	123,808,000
R & D EXPENDITURES	NA	NA	NA
SELL GEN & ADMIN EXP	52,017,000	105,065,000	53,318,000
INC BEF DEP & AMORT	87,160,000	-85,640,000	70,490,000
DEPRECIATION & AMORT	NA	NA	NA
NON-OPERATING INC	32,526,000	51,569,000	51,365,000
INTEREST EXPENSE	28,910,000	53,803,000	22,853,000
INCOME BEFORE TAX	90,776,000	-87,874,000	99,002,000
PROV FOR INC TAXES	42,490,000	18,707,000	42,635,000
MINORITY INT INCOME	839,000	2,081,000	1,864,000
INVEST GAINS/LOSSES	NA	NA	NA
OTHER INCOME	8,913,000	18,261,000	7,870,000
NET INC BEF EX ITEMS	56,360,000	-90,401,000	62,373,000
EX ITEMS & DISC OPS	NA	-328,012,000	NA
NET INCOME	56,360,000	-418,413,000	62,373,000
OUTSTANDING SHARES	NA	108,628,318	108,690,292

SEGMENT DATA: (SOURCE: 10-K 12/31/84)

	SALES	OP. INCOME
OIL FIELD SERVICES & PRODUCTS	3,176,339,000	478,558,000
INDST. ENG./CONST. SERVICES	1,574,292,000	8,299,000
MARINE ENG./CONST. SERVICES	695,088,000	11,033,000

FIVE YEAR SUMMARY

	SALES	NET INCOME	EPS
1984	5,445,700,000	329,600,000	2.87
1983	5,522,200,000	275,800,000	2.33
1982	7,257,300,000	496,800,000	4.21
1981	8,508,100,000	674,300,000	5.72
1980	7,090,000,000	500,300,000	4.25

MAGCOBAR DRESSER

```
CLRA      DRESSER - 7 OCCURRENCES 3 DOCUMENTS.

====> CLRA  SEARCH 2 - DOCUMENT 1 OF 3 (000069105) 1 PAGE
TITLE:
    CTL    RES    SIC      %      LEVEL / NAME
NAME:
    C=USA R=USA S=099 %=          01 DRESSER INDUSTRIES INC
SUBS:
    C=USA R=ONT S=352 %=100.00  02 DRESSER CANADA INC
    C=USA R=ONT S=791 %=100.00   03 DRESSER BAY STATE ABRASIVES CANADA
                                      LIMITED

AMERICAN DATA:

DISCLOSURE CO NO:   D824000000
COMPANY NAME:       DRESSER INDUSTRIES INC
CROSS REFERENCE:    NA
ADDRESS: THE DRESSER BUILDING
1505 ELM STREET
POST OFFICE BOX 718 DALLAS
TX 75221
TELEPHONE: 214-740-6000
INCORPORATION: DE
EXCHANGE: NYS
TICKER SYMBOL: DI
FORTUNE NUMBER: 0104
CUSIP NUMBER: 0002615979
D-U-N-S NO: 00-734-8295
SIC CODES: 3533 3532 3561 3825 3255 3536
PRIMARY SIC CODE: 3533
DESCRIPTION OF BUSINESS:
SUPPLIES TECHNOLOGY, PRODUCTS AND SERVICES TO INDUSTRIES INVOLVED IN
THE DEVELOPMENT OF ENERGY RESOURCES
 PROVIDES DRILLING FLUIDS AND OTHER DRILLING RELATED EQUIPMENT
 PRODUCES AND SELLS CHEMICALS USED IN THE REDUCTION OF CORROSION IN
OIL AND GAS PRODUCTION


OWNERSHIP:
CEDE & CO., 66% (PRX 02-15-85)
  ***
TYPE             DATE(Q,M)   OWNERS     CHANGE (000S) HELD   %OWN
INVEST. COS.     06/30/85(Q)                 0           0   0.00
INSTITUTIONS     06/30/85(Q)   185       2,441      46,320  61.94
5% OWNERS        07/31/85(M)     0          NA           0   0.00
INSIDERS         06/30/85(M)    14          NA         432   0.57
% OWNED MAY TOTAL ABOVE 100% DUE TO OVERLAPPING HOLDINGS REPORTS
```

SUBSIDIARIES:
AIRETOOL AND YOST SUPERIOR REALTY INC., 50%
ALDIA S. A., 49%
BARAMIN S.A. DE C. V., 49%
*BARMEX S.A., 50%
BARTIL INC., 50%
BAY STATE ABRASIVES S.A.
CENTRAL STANDARD AGENCY INC.
CETCO (CONSTRUCTION EQUIPMENT LTD.), 50%
CHINA PETROLEUM LOGGING-DRESSER ATLAS COOPERATION SERVICE CO., 50%
DIRELCO INC.
DRESSER AG (VADUZ)
*ABERDEEN BARYTES CO. LTD. →
**B.M.F. MINERALS (DERBYSHIRE) LTD. →
*ARABIAN MINERALS & CHEMICALS LTD., 50% →
*ARABIAN ROCK BITS AND DRILLING TOOLS CO., 50%
*DRESSER AL-RUSHAID MACHINERY CO. LTD., 50%
*DRESSER AL-RUSHAID VALVE AND INSTRUMENT CO. LTD., 50%
*DRESSER ATLAS ARABIA LTD., 51%
*DRESSER ATLAS ARGENTINA S.A.M.P.I.C.
*DRESSER AUSTRALIA PTY. LTD.
*DRESSER CAMEROUN S.A.R.L.
*DRESSER COTE D'IVOIRE S.A.R.L.
*DRESSER DE VENEZUELA C.A.
*DRESSER EUROPE S.A.
**DRESSER GABON S.A., 90%
**LODGE-COTTRELL LTD.
***BUELL LTD.
**W. U. DR. ING. A. GUILLEAUME GMBH & CO. KG
***ATLANTIC ITALIA MOLE ABRESIVE S.R.L. →
***ATLANTIC SLIJPPRODUCTEN B.V.
***MEULES ATLANTIC (S.A.R.L.)
***MEULES ATLANTIC BELGIUM S.A.
*DRESSER (FRANCE) S.A.
**DRESSER CONGO S.A.R.L.
*DRESSER INTERNATIONAL S.A.
*DRESSER JAPAN LTD.
*DRESSER NETHERLANDS B.V.
**LJUNGMANS INDUSTRIER AB **DEWRANCE & CO. LTD.
*DRESSER PRODUCTS S.A.
*DRESSER SINGAPORE PTE. LTD.
*DRESSER SOUTH AFRICA (PTY) LTD.
*INTERNATIONAL OIL FIELD ENGINEERING LTD., 51%
*MAGCOBAR (IRELAND) LTD
*MAGCOBAR MANUFACTURING NIGERIA LTD., 60%
MAGNESITAL-FEUERFEST GMBH, 50%
*OILFIELD MINERALS & CHEMICALS SDN. BHD., 49% →
*P.T. DRESSER MAGCOBAR INDONESIA, 60%
*THAILAND BARITE CO. LTD., 80% →
DRESSER AG (ZUG)
*DRESSER (KUWAIT) S.A.K., 49%
*DRESSER NIGERIA LTD., 60%
*MAGCOBAR (LIBYA) LTD., 49%
DRESSER CANADA INC.
*BOYLES BROS. DRILLING CO. LTD.

*FOYNES MANUFACTURING LTD.
DRESSER DO BRASIL LTDA.

*DRESCON PRODUTOS DE PERFURACAO S.A., 49%
*MELBAR PRODUTOS DE LIGNINA LTDA., 50%

DRESSER FINANCE CORP.
*DRESSER LEASING CORP.

DRESSER INDUSTRIA E COMERCIO LTDA.
DRESSER INTERNATIONAL SALES CORP.

DRESSER INVESTMENTS N.V.
DRESSER STANDARD INC.

*RELIANCE STANDARD LIFE INSURANCE CO.
**DRESSER INSURANCE CO.

DRESSER MACHINERY LTD.
DRESSER MINERACAO LTDA., 99%

DRESSSER MINERALS INTERNATIONAL INC. →
DRESSER NORWAY A/S

DRESSER OVERSEAS FINANCE N.V. DRESSER SERVICES INC.
DRESSER TRANSPORTATION SERVICES INC.

HARBISON A.C.I. PTY. LTD., 51%
INDUSTRIAS FLIR S.A., 49%

*RAFRACTARIOS H-W FLIR S.A.
**COMPANIA MINERA NOREX S.A.

*RAFRACTARIOS H-W FLIR DE MEXICO S.A.
JEFFREY MANUFACTURERA MEXICANA S.A. DE C.V.

MEC-TRACK S.P.A., 50%
MYKOBAR MINING CO. S.A.

NILE OILFIELD ENGINEERING LTD., 51%
P&S PROPERTY CO. LTD., 49%

PROPERTY AND CASUALTIY INSURANCE LTD.
RADIO MAGCOBAR INC.

REFRACTARIOS CHILENOS S.A. 69.36%
*CONSTRUCCIONES REFRACTARIAS RECSA LTDA., 99%

REFRACTARIOS PERUANOS S.A., 53.65%
SWACO EQUIPOS S.A. DE C.V., 49%

SYMINGTON WAYNE OVERSEAS LTD.
*SYMINGTON WAYNE INTERNATIONAL CO. LTD.

TITAN SERVICES INC., 84%
*TITAN PUMPING SERVICES INC.

TRICONOS MINEROS S.A.
TURBO PRODUCTOS DRESSER S.A. DE C.V.

INCOME STATEMENT

QUARTERLY REPORT FOR:	01/31/85	04/30/85	07/31/85
NET SALES	903,700,000	1,034,600,000	1,057,300,000
COST OF GOODS	653,000,000	739,200,000	768,000,000
GROSS PROFIT	250,700,000	295,400,000	289,300,000
R & D EXPENDITURES	NA	NA	NA
SELL GEN & ADMIN EXP	228,600,000	257,600,000	268,500,000
INC BEF DEP & AMORT	22,100,000	37,800,000	20,800,000
DEPRECIATION & AMORT	NA	NA	NA
NON-OPERATING INC	8,900,000	10,700,000	8,500,000
INTEREST EXPENSE	18,700,000	21,100,000	20,100,000
INCOME BEFORE TAX	12,300,000	27,400,000	9,200,000
PROV FOR INC TAXES	4,600,000	10,600,000	1,500,000
MINORITY INT INCOME	NA	NA	NA
INVEST GAINS/LOSSES	NA	NA	NA
OTHER INCOME	7,600,000	6,500,000	6,300,000
NET INC BEF EX ITEMS	15,300,000	23,300,000	14,000,000
EX ITEMS & DISC OPS	NA	NA	NA
NET INCOME	15,300,000	23,300,000	14,000,000
OUTSTANDING SHARES	NA	76,139,068	76,215,449

SEGMENT DATA: (SOURCE: 10-K 10/31/84)

	SALES	OP. INCOME
PETROLEUM OPERATIONS	1,368,100,000	76,200,000
ENERGY PROCESSING & CONVERSION	656,400,000	49,500,000
MINING & CONSTRUCTION EQUIP.	851,700,000	25,500,000
GENERAL INDUSTRY	876,900,000	50,700,000

FIVE YEAR SUMMARY

	SALES	NET INCOME	EPS
1984	3,732,400,000	96,700,000	1.24
1983	3,473,400,000	5,100,000	0.06
1982	4,160,600,000	172,300,000	2.19
1981	4,614,500,000	316,600,000	4.04
1980	4,016,300,000	261,100,000	3.35

ANNUAL SHAREHOLDERS MEETING 03-22-84 (10-Q 04-30-84) ,APPROVAL, TO SIGN SULLIVAN PRINCIPLLES ANNUAL SHAREHOLDERS MEETING 03-22-84 (10-Q

DOWELL SCHLUMBERGER

```
CLRA      SCHLUMBERGER - 3 OCCURRENCES 1 DOCUMENTS.

====> CLRA  SEARCH 5 - DOCUMENT 1 OF 1 (000281605) 1 PAGE
TITLE:
     CTL    RES    SIC      %      LEVEL / NAME
NAME:
    C=NLD R=NLD S=000 %=           01 SCHLUMBERGER BV
SUBS:
    C=NLD R=ALT S=099 %=100.00  02 SCHLUMBERGER CANADA LTD
    C=NLD R=USA S=000 %=100.00  02 SCHLUMBERGER TECHNOLOGY CORPORATION
    C=NLD R=ONT S=623 %=100.00   03 MANUFACTURING DATA SYSTEMS
                                     INTERNATIONAL CANADA LIMITED

AMERICAN DATA


DISCLOSURE CO NO:   S116100000
COMPANY NAME:       SCHLUMBERGER LTD
CROSS REFERENCE:    NA
ADDRESS: 277 PARK AVENUE NEW YORK NY 10172
TELEPHONE: 212-350-9400
INCORPORATION: NETHERLANDS ANTILLES
EXCHANGE: NYS
TICKER SYMBOL: SLB
FORTUNE NUMBER: NA
CUSIP NUMBER: 0008068570
D-U-N-S NO: 00-185-4546
SIC CODES: 1389 1381 3825 3824 3823 3674
PRIMARY SIC CODE: 1389
DESCRIPTION OF BUSINESS:
PROVIDES OILFIELD SERVICES TO PETROLEUM INDUSTRY
 ALSO MANUFACTURES AND SELLS MEASUREMENT, DISPLAY AND CONTROL
PRODUCTS AND COMPONENTS.
CURRENT OUTSTANDING SHARES:    299,582,876 (SOURCE: 10-Q      04/30/85)
SHARES HELD BY OFF & DIR:          761,902 (SOURCE: PROXY)
SHAREHOLDERS:                       39,000 (SOURCE: 10-K)
EMPLOYEES:                          80,000 (SOURCE: 10-K)
FISCAL YEAR END: 12/31
```

```
OWNERSHIP:
TYPE            DATE(Q,M)  OWNERS     CHANGE (000S) HELD  %OWN
INVEST. COS.    06/30/85(Q)                0          0   0.00
INSTITUTIONS    06/30/85(Q)  454         777    126,515  42.07
5% OWNERS       07/31/85(M)    0          NA          0   0.00
INSIDERS        06/30/85(M)   37          NA      5,620   1.86
% OWNED MAY TOTAL ABOVE 100% DUE TO OVERLAPPING HOLDINGS REPORTS

SUBSIDIARIES:
SCHLUMBERGER B. V., NETHERLANDS
*SOCIETE DE PROSPECTION ELECTRIQUE SCHLUNBERTER, FRANCE
**FLOPETROS, S. A., FRANCE
**FOREX NEPTUNE, S. A., FRANCE
*COMPAGNIE DES COMPTEURS, S. A., FRANCE
**ENERTEC S. A., FRANCE
**FLONIC S. A., FRANCE
**SEREG S. A., FRANCE
*SCHLUMBERGER CANADA LTD., CANADA
*SCHLUMBERGER MEASUREMENT & CONTROL (UK) LTD., UNITED KINGDOM
NEPFOR LTD., NETHERLANDS ANTILLES
SCHLUMBERGER OFFSHORE SERVICES LTD., NETHERLANDS ANTILLES
SEA AND LAND DRILLING CONTRACTORS INC., PANAMA
TRITON INDUSTRIES INC., PANAMA
FLOPETROL HOLDING LTD., BRITISH VIRGIN ISLANDS
FOREX NEPTUNE INTERNATIONAL INC., PANAMA
ANALYSTS INTERNATIONAL, S. A., THE, PANAMA
BVI HOLDINGS LTD., BRITISH VIRGIN ISLANDS
FAIRCHILD SEMICONDUCTOR (HONG KONG) LTD., HONG KONG
M C & C HOLDINGS LTD, BRITISH VIRGIN ISLANDS
SCHLUMBERGER OVERSEAS, S. A., PANAMA
*DOWELL SCHLUMBERGER CORP., PANAMA, 50%
SCHLUMBERGER SURENCO, S. A., PANAMA
SCHLUMBERGER TECHNOLOGY CORP., TEXAS
*AMALYSTS INC., THE, TEXAS
*DOWELL SCHLUMBERGER INC., DELAWARE, 50%
*FAIRCHILD CAMERA AND INSTRUMENT CORP., DELAWARE
*SCHLUMBERGER SYSTEMS INC., DELAWARE
*SANGAMO WESTON INC., DELAWARE


INCOME STATEMENT

  QUARTERLY REPORT FOR:    03/31/85        06/30/85
NET SALES               1,587,442,000  1,520,493,000
COST OF GOODS             980,641,000    988,490,000
GROSS PROFIT              606,801,000    532,003,000
R & D EXPENDITURES         97,537,000    105,113,000
SELL GEN & ADMIN EXP      164,413,000    219,480,000
INC BEF DEP & AMORT       344,851,000    207,410,000
DEPRECIATION & AMORT               NA             NA
NON-OPERATING INC         105,485,000    115,852,000
INTEREST EXPENSE           51,849,000     59,306,000
INCOME BEFORE TAX         398,487,000    263,956,000
PROV FOR INC TAXES         94,953,000     51,902,000
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MINORITY INT INCOME                    NA            NA
INVEST GAINS/LOSSES                    NA            NA
OTHER INCOME                           NA            NA
NET INC BEF EX ITEMS          303,534,000   212,054,000
EX ITEMS & DISC OPS                    NA            NA
NET INCOME                    303,534,000   212,054,000
OUTSTANDING SHARES                     NA   298,624,599

SEGMENT DATA:  (SOURCE: 10-K 12/31/84)
                                                SALES    OP. INCOME
 OILFIELD SERVICES                          3,617,000     1,170,000
 CONTROL & COMPONENTS                       2,392,000       161,000

FIVE  YEAR  SUMMARY

                  SALES         NET INCOME         EPS
 1984         6,370,000          1,182,000        4.10
 1983         5,797,000          1,084,000        3.73
 1982         6,284,000          1,348,000        4.60
 1981         5,978,000          1,266,000        4.37
 1980         5,137,000            994,000        3.47
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OTHER CORPORATE EVENTS:
ELECTION, MICHEL VAILLAUD AS CHAIRMAN, PRESIDENT AND CHIEF EXECUTIVE
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BAROID OF CANADA

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TITLE:
    CTL    RES    SIC      %       LEVEL / NAME
NAME:
   C=USA R=USA S=000 %=          01 NL INDUSTRIES INC.
SUBS:
   C=USA R=ALT S=629 %=100.00   02 BAROID OF CANADA LTD
   C=USA R=ALT S=727 %=098.00   02 CANADIAN BAROID SALES LTD
   C=USA R=USA S=987 %=100.00   02 NATIONAL LEAD COMPANY (CDN.BR.) →
   C=USA R=ONT S=298 %=049.99   02 THE CANADA METAL COMPANY LTD. →
   C=USA R=QUE S=378 %=100.00   02 NL CHEM CANADA INC
   C=USA R=USA S=000 %=100.00   02 RUCKER CO.
   C=USA R=BC  S=623 %=100.00    03 NL RUCKER PRODUCTS LTD.
   C=USA R=BC  S=623 %=100.00    03 N L RUCKER PRODUCTS LTD
   C=USA R=USA S=000 %=100.00    03 HYCALOG INC.
   C=USA R=BC  S=896 %=099.95     04 HYCALOG CANADA LTD
   C=USA R=USA S=000 %=100.00    03 SHAFFER WESTERN HEMISPHERE INC
   C=USA R=USA S=623 %=100.00     04 SHAFFER WESTERN HEMISPHERE INC.
                                       (CDN.BR.)
   C=USA R=USA S=000 %=100.00   02 FLOATING FLOORS INC.
   C=USA R=USA S=000 %=100.00   02 SPERRY SUN INC.
   C=USA R=ALT S=899 %=100.00    03 NL SPERRY-SUN OF CANADA LTD


AMERICAN DATA

DISCLOSURE CO NO:   N002500000
COMPANY NAME:       N L INDUSTRIES INC
CROSS REFERENCE:    WAS NATIONAL LEAD CO
TELEPHONE: 212-621-9400
INCORPORATION: NJ
EXCHANGE: NYS
TICKER SYMBOL: NL
FORTUNE NUMBER: 0248
CUSIP NUMBER: 0006291561
D-U-N-S NO: 00-131-7577
SIC CODES: 3533 2899 1389 2816
PRIMARY SIC CODE: 3533
DESCRIPTION OF BUSINESS:
SUPPLIES PRODUCTS, SERVICES, AND EQUIPMENT FOR OIL AND GAS INDUSTRY
 AND PRODUCES AND SUPPLIES SPECIALTY PIGMENTS, RHEOLOGICAL AGENTS,
AND CHEMICAL SPECIALTIES
  ALSO MINES ILMENITE ORES
 AND PRODUCES TITANIUM METAL SPONGE, INGOT, AND MILL PRODUCTS.

CURRENT OUTSTANDING SHARES:    62,077,949 (SOURCE: 10-Q        06/30/85)
SHARES HELD BY OFF & DIR:         443,957 (SOURCE: PROXY)
SHAREHOLDERS:                      42,760 (SOURCE: 10-K)
EMPLOYEES:                         12,850 (SOURCE: 10-K)
FISCAL YEAR END: 12/31
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OWNERSHIP:
BATTERYMARCH FINANCIAL MGMT, 5.2% (PRX 03-21-85)
  ***
TYPE           DATE(Q,M)  OWNERS     CHANGE (000S) HELD  %OWN
INVEST. COS.   06/30/85(Q)                0           0  0.00
INSTITUTIONS   06/30/85(Q)  117       1,309      31,481 50.71
5% OWNERS      07/31/85(M)    1          NA       3,199  5.15
INSIDERS       06/30/85(M)   25          NA         515  0.83
% OWNED MAY TOTAL ABOVE 100% DUE TO OVERLAPPING HOLDINGS REPORTS

SUBSIDIARIES:
THE RUCKER CO.
*NL RUCKER PRODUCTS LTD.
*SHAFFER WESTERN HEMISPHERE INC.
BAROID INTERNATIONAL PETROLEUM SERVICES INC.
BAROID SALES EXPORT CORP.
NALDYNE INTERNATIONAL SALES CORP.
NATIONAL LEAD OVERSEAS CAPITAL CORP. NL-BAROID MINERALS INC.
NL CHEMICALS EUROPE INC.
NL U.S. CHEMICALS INC.
NL SPERRY-SUN INC.
*SPERRY-SUN OF CANADA LTD.
*NL INTERNATIONAL INC.
PACIFIC PETROLEUM PRODUCTS INC.
*MINERALES ANDINOS S.A.
R-N CORP.
SW SERVICING INC.
TITANIUM METALS CORP. OF AMERICA
ATLANTIC MINERALS & PRODUCTS CORP.
NL PETRO-LOG INC.
INLAND WELL SERVICE
ENENCO INCORP.
NL INDIA INC.
OILFIELD TECHNOLOGY INTERNATIONAL INC.
NLO INC.
COCHRAN-DEAN CO.
BASIN SURVEYS INC.
BAROID AUSTRALIA PTY. LTD.
BARBADOS OIL FIELD SERVICES LTD.
NL CHEMICALS S.A./N.V.
NL INSURANCE LTD.
BAROID MINERO BOLIVIA LTD.
BAROID PIGMINA INDUSTRIAL E COMERCIAL S.A.
SPERRY-SUN DO BRAZIL SERVICOS TECHNICOS LTD.
NL BAROID (CAMEROON) S.A.R.L.
BAROID OF CANADA LTD.
CANADIAN BAROID SALES LTD.
NL CHEM CANADA INC.
BAROID CARIBBEAN LTD.
BAROID FRANCE S.A.
SOCIETE INDUSTRIELLE DU TITANE
BENTONE-CHEMIE G.M.B.H.
KRONOS TITAN G.M.B.H.
SCHRAUBENFABRIK NEUSTADT GOETZ & CIE G.M.B.H.
NL CHEMICALS (U.K.) LTD.
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*ABBEY CHEMICALS LTD.
*BENTONE-SUD S.A.
NL INDUSTRIES (U.K.) LTD.
*NL OVERSEAS SERVICE CO. LTD.
*NL PETROLEUM SERVICES (U.K.) LTD.
*NL PETROLEUM PRODUCTS LTD.
*SPERRY-SUN U.K. LTD.
*RUSSELL ATTITUDE SYSTEMS
BAROID INTERNATIONAL S.P.A.
NL-TEIJIN CO. LTD.
LIBYAN BAROID CO. LTD.
BAROID MALAYSIA SENDIRIAN BERHAD
BAROID DE MEXICO S.A.
SHAFFER DE MEXICO S.A.
CEBO N.V.
BAROID DRILLING CHEMICALS PRODUCTS LTD.
BAROID OF NIGERIA LTD.
KRONOS TITAN A/S
*TITANIA A/S
NORSK PETROLEUM SERVICES A/S
PERUBAR S.A.
BAROID (SAUDI ARABIA) LTD.
SPERRY-SUN SAUDI ARABIA LTD.
PETROLEUM INFORMATION EQUIPMENT AND SERVICES PTE. LTD.
NL PETROLEUM SERVICES (FAR EAST) PTE. LTD.
AMERICAN THAI BARITE LTD.
SIAM AMERICAN MINING CO. LTD.
THAI ENDEAVOR LTD.
BUDIN BARIT KIMAYA SANAYI A.S.
BAROID TRINIDAD SERVICES LTD.
ABU DHABI DRILLING CHEMICALS AND PRODUCTS LTD.
BAROID DE VENEZUELA S.A.
P.T. BAROID INDONESIA

INCOME STATEMENT

QUARTERLY REPORT FOR:	03/31/85	06/30/85
NET SALES	327,421,000	358,054,000
COST OF GOODS	229,025,000	247,032,000
GROSS PROFIT	98,396,000	111,022,000
R & D EXPENDITURES	NA	NA
SELL GEN & ADMIN EXP	84,155,000	84,782,000
INC BEF DEP & AMORT	14,241,000	26,240,000
DEPRECIATION & AMORT	NA	NA
NON-OPERATING INC	8,709,000	3,770,000
INTEREST EXPENSE	9,967,000	9,750,000
INCOME BEFORE TAX	12,983,000	20,260,000
PROV FOR INC TAXES	8,569,000	13,371,000
MINORITY INT INCOME	NA	NA
INVEST GAINS/LOSSES	NA	NA
OTHER INCOME	NA	NA
NET INC BEF EX ITEMS	4,414,000	6,889,000
EX ITEMS & DISC OPS	NA	NA
NET INCOME	4,414,000	6,889,000
OUTSTANDING SHARES	62,078,682	62,077,949

SEGMENT DATA: (SOURCE: 10-K 12/31/84)

	SALES	OP. INCOME
PETROLEUM SERVICES OPERATIONS	887,528,000	-1,503,000
CHEMICALS OPERATIONS	472,591,000	94,717,000

FIVE YEAR SUMMARY

	SALES	NET INCOME	EPS
1984	1,360,119,000	-132,735,000	-2.20
1983	1,354,611,000	-47,239,000	-0.83
1982	2,088,149,000	185,274,000	2.84
1981	2,280,340,000	254,368,000	3.76
1980	1,660,962,000	121,137,000	1.77

ANNOUNCEMENT, 08-22-85, EXPANSION OF NL CHEM CANADA INC. TITANIUM DIOXIDE PLANT (8-K 08-22-85) ANNOUNCEMENT, 10-10-84, PURCHASE OF TITANIUM DIOXIDE PIGMENT BUSINESSFROM AMERICAN CYANAMID CO. (8-K 10-10-84)

AGREEMENT, TO SALE 90% OF TIMET DIVISION OF TITANIUM METALS CORP. TO AGROUP OF INVESTORS AND KELSO & CO., 12-31-84 (8-K 12-31-84)

ANNOUNCEMENT, ESTABLISHMENT OF JOINT VENTURE WITH POOL COMPANY FOR OPERATION WELL SERVICING RIGS AND RELATED ASSETS IN NORTH DAKOTA, MONTANA, AND PORTIONS OF COLORADO, NEW MEXICO AND UTAH, 01-15-85, (8-K 01-15-85)

NOWSCO WELL SERVICE LTD.

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====> CLRA  SEARCH 8 - DOCUMENT 1 OF 1 (000058900) 1 PAGE

TITLE:
     CTL    RES    SIC      %      LEVEL / NAME
NAME:
   C=USA P=USA S=000 %=        01 BIG THREE INDUSTRIES INC.
SUBS:
   C=USA R=ALT S=099 %=061.50  02 NOWSCO WELL SERVICE LTD
   C=USA R=ALT S=899 %=100.00   03 NOWSCO OF CANADA LTD
   C=USA R=USA S=000 %=100.00  02 BOWEN TOOLS INC.
   C=USA R=ALT S=623 %=099.91   03 BOWEN TOOLS LTD


AMERICAN DATA

DISCLOSURE CO NO:   B474300000
COMPANY NAME:       BIG THREE INDUSTRIES INC
CROSS REFERENCE:    WAS BIG THREE INDUSTRIAL GAS & EQUIP CO
ADDRESS: 3535 WEST TWELFTH STREET HOUSTON
TX 77006
TELEPHONE: 713-868-0333
INCORPORATION: TX
EXCHANGE: NYS
TICKER SYMBOL: BIG
FORTUNE NUMBER: 0360
CUSIP NUMBER: 0000896712
D-U-N-S NO: 00-806-6391
SIC CODES: 3533 2813 3623 3629 5084 1389
PRIMARY SIC CODE: 3533
DESCRIPTION OF BUSINESS:
ENGAGED IN THE RECOVERY AND SALE OF ATMOSPHERIC INDUSTRIAL GASES
MANUFACTURES AND SELLS OILFIELD EQUIPMENT AND SUPPLIES, AND PROVIDES
OILFIELD SERVICES
 DISTRIBUTES WELDING AND INDUSTRIAL EQUIPMENT AND SUPPLIES.

CURRENT OUTSTANDING SHARES:     38,477,804 (SOURCE: 10-Q      07/31/85)
SHARES HELD BY OFF & DIR:        3,836,011 (SOURCE: PROXY)
SHAREHOLDERS:                        5,308 (SOURCE: 10-K)
EMPLOYEES:                              NA
FISCAL YEAR END: 12/31
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OWNERSHIP:
SAROFIM, FAYEZ S., 6.8% (PRX 03-22-85)
  ***
TYPE             DATE(Q,M)   OWNERS      CHANGE (000S) HELD   %OWN
INVEST. COS.     06/30/85(Q)                  0            0  0.00
INSTITUTIONS     06/30/85(Q)   100          297       19,040 48.95
5% OWNERS        07/31/85(M)     1           NA        2,640  6.78
INSIDERS         06/30/85(M)    27           NA        4,071 10.46
% OWNED MAY TOTAL ABOVE 100% DUE TO OVERLAPPING HOLDINGS REPORTS

SUBSIDIARIES:
BIG THREE COGENERATION INC.
BIG THREE INTERNATIONAL INC., DELAWARE
BIG THREE INTERNATIONAL INC., VIRGIN ISLANDS
BIG THREE LINCOLN ALASKA INC., 51%
BIG THREE LINCOLN (U.K.) LTD., 51%
BIG THREE DE MEXICO S.A.
BIG THREE PIPELINE CO.
BOWEN TOOLS INC., DELAWARE
*BOWEN TOOLS INC., TEXAS
**BOWEN MEXICANA S.A. DE C.V.
**BOWEN TOOLS TLD.
INDUSTRIAL WATER TREATMENT CO.
LINCOLN BIG THREE INC.
NOWSCO SERVICES INC.
NOWSCO WELL SERVICE LTD., 62%
*N.W.S. ADMINISTRATIVE LTD.
*NOWSCO OF CANADA LTD.
*NOWSCO INTERNATIONAL LTD.
*NOWSCO (NETH) GROUP B.V.
**NOWSCO (IFC) B.V.
*NOWSCO (U.K.) GROUP LTD. **NOWSCO WELL SERVICE (U.K.) LTD.
*NOWSCO WELL SERVICE CO. LTD.
*NOWSCO WELL SERVICE (EUROPE) B.V.
**NOWSCO WELL SERVICE NORGE A/S
*NOWSCO WELL SERVICE GMBH
*NOWSCO WELL SERVICE INTERNATIONAL LTD.
*NOWSCO WELL SERVICE (S.E. ASIA  PTE. LTD.
*NOWSCO WELL SERVICE SRL.
THE DIA-LOG CO.RVICE
*THOR-JET INC.
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INCOME STATEMENT

QUARTERLY REPORT FOR:	03/31/85	06/30/85
NET SALES	196,167,000	210,598,000
COST OF GOODS	117,716,000	127,609,000
GROSS PROFIT	78,451,000	82.989.000
R & D EXPENDITURES	NA	NA
SELL GEN & ADMIN EXP	31,684,000	32,683,000
INC BEF DEP & AMORT	46,767,000	50,306,000
DEPRECIATION & AMORT	21.028,000	22,731,000
NON-OPERATING INC	844,000	1,399,000
INTEREST EXPENSE	4,429,000	4,620,000
INCOME BEFORE TAX	22,154,000	24,354,000
PROV FOR INC TAXES	8,349,000	8,576,000
MINORITY INT INCOME	2.327,000	3,371,000
INVEST GAINS/LOSSES	NA	NA
OTHER INCOME	NA	NA
NET INC BEF EX ITEMS	11,478,000	12,407.000
EX ITEMS & DISC OPS	NA	NA
NET INCOME	11.478,000	12,407,000
OUTSTANDING SHARES	NA	NA

SEGMENT DATA: (SOURCE: 10-K 12/31/84)

	SALES	OP. INCOME
ENERGY RELATED	360,725,000	50,737,000
INDUSTRIAL GAS	339,220,000	75,523,000
WELDIN EQUIPMENTM	79,922,000	-4,466,000

FIVE YEAR SUMMARY

	SALES	NET INCOME	EPS
1984	775,678.000	56,696,000	1.40
1983	668.841,000	45,331,000	1.07
1982	767.725,000	86,812,000	2.05
1981	823.280,000	108,854,000	2.57
1980	659.121,000	86,604,000	2.05